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THE OPENING OF THE VICTORIA FALLS BRIDGE.*

By HAROLD SHEPSTONE.

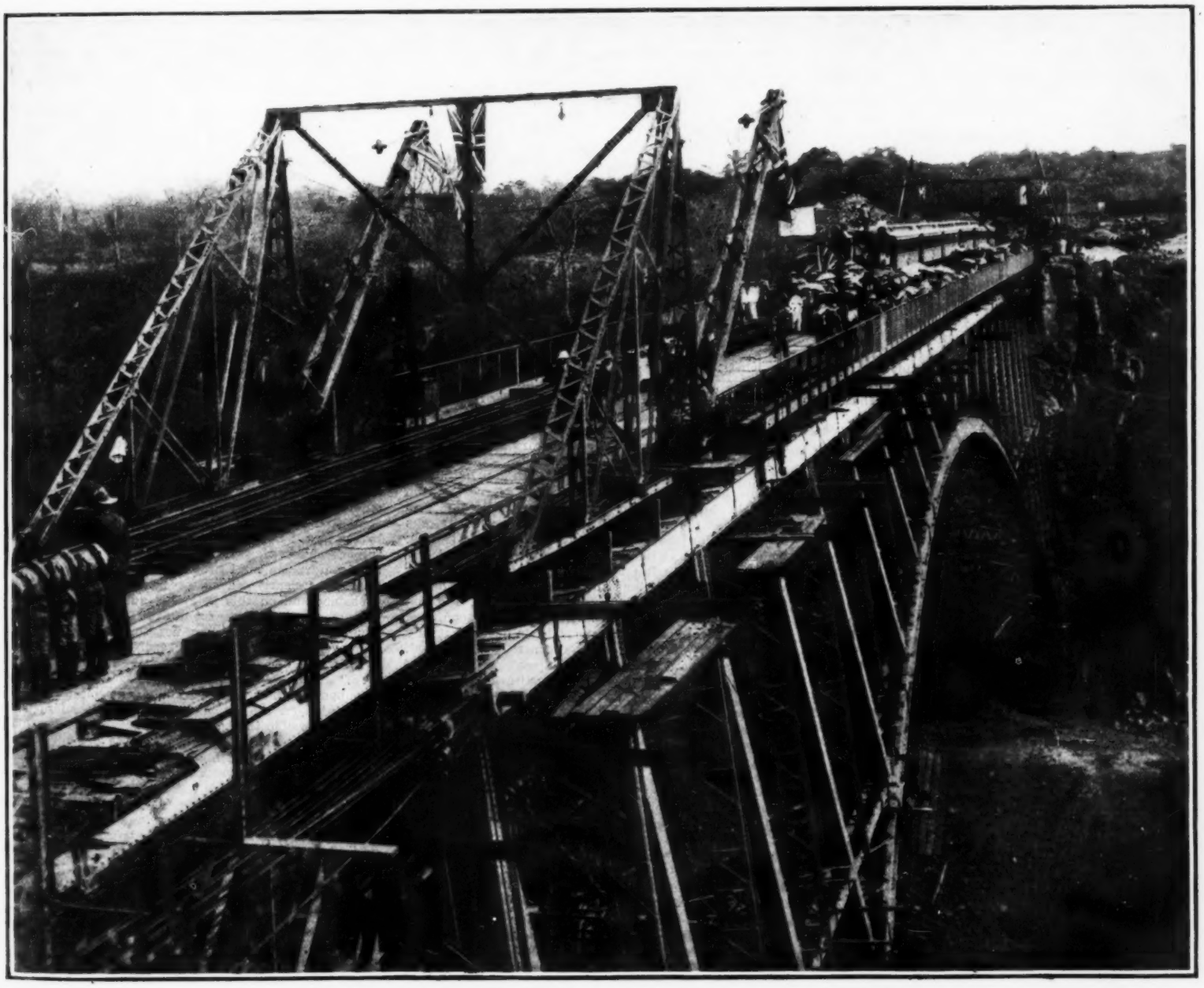
THE Victoria Falls Bridge over the Zambesi gorge in central Africa was formally opened on September 12 last by Prof. Darwin, head of the British Association, which has been touring and lecturing in South Africa. An inspection of the mighty falls and a ride in an up-to-date railroad coach across the highest bridge in the world in the very heart of Africa was a fitting climax to the tour which the members of the association have made in this part of the world.

As this interesting engineering feat has already been described in the pages of the SCIENTIFIC AMERICAN, only a brief reference to the bridge need be made here. It is a combination of girder and arch, has a total length of 650 feet, and consists of three spans, the center one being 500 feet in length, and the two approach spans having a length of 87 feet 6 inches and 62 feet 6 inches respectively. It was erected from each side simultaneously on the cantilever principle. Perhaps the most interesting feature of the whole undertaking was the method the engineers adopted in tying the weight back to the sides of the bank until the two portions of the bridge met in the center. This was necessary as the structure represents a total weight of 2,000 tons. Two bore holes were sunk on each bank, 30 feet deep and 30 feet apart, and the two extremities joined together by boring

Length, 650 feet; height above water, 400 feet; width of roadway, 30 feet.

THE COMPLETED VICTORIA FALLS BRIDGE.

*Specially prepared for the SCIENTIFIC AMERICAN SUPPLEMENT



THE OPENING OF THE VICTORIA FALLS BRIDGE BY PROF. DARWIN.

through the rock. Wire ropes suspending the weight of each half of the great structure were passed through these borings, and in this way a huge solid mass of rock on each side of the bank was made to sustain the weight of the bridge. The bridge has a clear width of roadway of 30 feet, sufficient for a double set of rails. As will be seen from a close inspection of one of our photographs taken during the opening ceremony, only one line of rails has so far been laid down.

Prof. Darwin formally declared the bridge open from the front of a locomotive which was decorated with two enormous British flags. The train drew up in the middle of the bridge, and the professor, on the invitation of Sir Charles Metcalfe, the engineer to the Rhodesian government, gave an address. His remarks were very fitting for the occasion. It seemed nothing short of a fairy tale, he declared, to stand on this bridge over the Zambesi. It was due to the influence of steam that this great enterprise had become possible. Then, touching a button with a staff the cord stretching across the roadway was fused and the first train steamed across. The staff which Prof. Darwin used was an exquisite piece of workmanship, made of Zambesi wood and beautifully polished. On the apex of the staff is a disk cunningly engraved, showing a view of the Falls with the bridge across. The disk is encircled with an enameled wreath. On the front of the staff is a gold plate upon which is engraved: "Presented to Prof. Darwin, in commemoration of his opening of the Victoria Falls Bridge over the Zambesi River during the visit of the British Association, September 12th, 1905." Over 600 persons witnessed this interesting ceremony in Central Africa. Indeed, it took five special trains to bring the visitors from Bulawayo to the Victoria Falls.

These trains were so timed as to reach the Falls before sunrise, in order to give the members of the British Association an opportunity of seeing the finest falls in the world as the sun peeped over the hills. A sunrise at the Victoria Falls is an amazingly beautiful spectacle. After the bridge had been declared open most of the visitors spent the remainder of the day in viewing the Falls from different points. A constant stream of canoes carried enhusiasts to and from Livingstone Island, so called because of the tree whereon the explorer carved his initials. They were particularly struck with the wonderful forms of vegetation and flowers that can be found on this island and in the neighborhood of the Falls. Some of these flowers are absolutely unknown. A bulb from the Victoria Falls recently arrived at Kew Gardens, London. It threw up five spikes of bloom of a lovely yellow tint. Sir W. T. Thiselton-Dyer, after examining it, wrote as follows: "It seems to us quite unique, and a brilliant discovery; it ought to be a starting point to a new race of garden gladioli."

The Victoria Falls bridge, of course, carries the track of the Cape-to-Cairo Railroad. From Cape Town to the Falls by rail is a distance of 1,631 miles, and the journey can be accomplished in about three and a half days. Indeed, you can reach the Falls from London in twenty-one days. Nothing could more emphasize the white man's grip upon Central Africa than the Victoria Falls bridge and its railroad. But the question one naturally asks is, "When will the railroad between Cape Town and Cairo be completed?" It may be many years; but, on the other hand, a rapid through communication is quite within measurable distance. Three hundred and fifty miles north of the Falls are great copper deposits, and the railroad is at once to be extended to them. In fact, 170 miles of this section has been completed. Then we touch Lake Tanganyika, which is some 400 miles in length. A railroad there is unnecessary, as commodious steamers will be placed upon its waters, and the same remark applies to the other two lakes and the Nile. Thus, out of a total distance of 5,611 miles which separates Cape Town from Cairo, no fewer than 1,800 miles will be performed by steamer, leaving 3,811 miles to be accomplished by rail. Of this distance 2,940 miles are already built, leaving only 871 miles to be constructed to obtain through communication. Just now the engineers are pushing the line northward at the rate of over a mile a day. Indeed, during a day of twelve working hours, 5¾ miles of track were recently laid, which constitutes a world's record.

SUBMARINES.—VII.*

By SIR WILLIAM H. WHITE, K.C.B.

IN the opinion of officers who gave evidence, previous experience had shown no reason to doubt the safety of "A 8" when driven at 10 knots, with a reserve of buoyancy of six tons excluding the conning tower. Capt. Bacon was convinced that, unless the reserve of buoyancy was reduced to 3½ tons, and the trim altered from four degrees by the stern to one degree by the bow, the vessel could not be made to dive; but he stated that his conclusion was based on model experiments, and that a model of "A 8" had not then been tried. He dwelt upon the possibility of water having entered forward through an open rivet-hole (¾ inch in diameter), and estimated that one ton might have entered during the ten minutes that the vessel was steaming ahead. He was under the impression that "one rivet was found to be out when the boat was docked," but he remarked that "it was impossible to say whether this was out before or after the accident." Later evidence, however, indicated that no rivet was out and that no open rivet hole admitted water. One rivet was "loose" in the forward petrol tank, and consequently it was impossible that during the ten minutes even the ton of water mentioned by Capt. Bacon could have entered, whereas his hypothesis required the entry of 2½ tons. There was, in fact, no proof or suggested possibility of any means by which 2½ tons of water could have entered the forward part of "A 8" in the short time she was under way, and it is in the highest degree improbable that such water did enter.

Capt. Lees (inspecting captain of submarines) did not support Capt. Bacon's view or consider it probable that water entered forward and caused the bow to dip. On the contrary, he expressed the opinion that while the dip of the bow "might be largely due to the use of the diving helm, this would require some assistance in the nature of trim to bring about what actually took place—*unless the inclination down is the effect of the shape of the boat herself at a certain speed and trim.*" The words in italics exactly indicate the view which the writer held and expressed previously to the accident; and such an opinion coming from an experienced officer who carefully investigated all the circumstances of this accident must carry much weight. The matter is of the greatest importance and obviously demands exhaustive experimental investigation.

In this connection reference must be made to a significant statement as to the previous behavior of "A 8" during her passage round from Barrow, made to the court martial by Lieut. Addison, the officer who was in charge. Up to the present time the only reports of the evidence available are those published in the press, although the great importance of the subject makes it reasonable to hope that an official report will be published as a parliamentary paper, in accordance with precedents established by many past inquiries, including those into the loss of the "Vanguard," "Captain," "Atalanta," and "Victoria." Taking the excellent and apparently verbatim reports of the Plymouth journals, the statement of Lieut. Addison was as follows: On the passage from Barrow "A 8" had her full reserve of buoyancy (about 16 tons including conning tower), and her maximum longitudinal stability. Only 10 degrees of helm was used for the horizontal rudders, and their observed effect was to alter the trim about two degrees at a speed of nine knots. The court inquired what was the maximum angle of helm and was told that it was 35 degrees. Lieut. Candy asked a number of questions as to the possible effect of rapid and large changes in the helm-angle on the trim of "A 8"; but Lieut. Addison stated he had no experience of these conditions. The evidence of Lieut. Addison affords a means of approximating closely to the probable effect of the horizontal rudders in changing the trim of "A 8" at the time of the accident, when her reserve of buoyancy was six tons (excluding conning tower), her longitudinal stability only 73 per cent of that in the passage-condition, and her speed ten knots. The higher speed would increase the rudder pressure nearly 25 per cent; and, with the same angle of helm, "A 8," when endowed with her full buoyancy and stability, would have changed trim about 2½ degrees, instead of 2 degrees observed at 9 knots. As the buoyancy was diminished by seven tons the longitudinal stability was decreased by 27 per cent and consequently the change of trim with ten degrees of helm and speed of ten knots would become about 3.4 degrees. Supposing that the maximum angle of helm (35 degrees) was given, instead of 10 degrees used by Lieut. Addison, the rudder pressure would have been greatly increased, and its moment to change trim would have been at least doubled. Associating all these possible changes, and starting from the evidence of Lieut. Addison, it is a reasonable conclusion that the use of the full angle of helm for the horizontal rudders, if steadily applied, might have produced a change of trim in "A 8" at the time of the accident of six to seven degrees; and if the rudders were suddenly put "hard down" they might have caused a considerably greater temporary dip of the bow.

This estimate, based on recorded experience with "A 8," differs greatly from that which Capt. Bacon put before the court martial—viz., four degrees as the probable change of trim which the rudders could produce under the same conditions. The authority was not given for the calculations used by Capt. Bacon, which included estimates of rudder-pressures and moments to change trim; but it is probable that these, as well as the calculations for stability, were made by naval constructors. The evidence of Lieut. Addison was given subsequently to that of Capt. Bacon, and there is nothing in the reports to indicate that any comparison was made by the court between Capt. Bacon's estimate and Lieut. Addison's statement of actual performance. From its constitution the court could hardly be expected to deal with technical questions in detail, or to make approximations to the probable behavior of "A 8," at the time of the accident, on the basis of her observed behavior in another condition; but to the naval constructor such a course at once suggests itself as important and as preferable to pure calculation, for which the experimental data are admittedly incomplete.

In the opinion of the writer it is a matter for regret that no evidence was given before the court martial by competent naval architects, who had made thorough and independent investigations in regard to the stability and propulsive conditions of "A 8." The only technical witness called who had knowledge of the stability of "A 8" was Mr. Tierney, of the firm of Messrs. Vickers, Maxim & Co., and that witness appears to have been concerned with her construction in a subordinate capacity. His evidence had relation to matters of detail rather than of principle; and he stated that he had only witnessed trials of "A 8" at her light draft, and this from a tender. All the figures on which the foregoing remarks have been based were presented to the court by Capt. Bacon, who stated at the Institution of Naval Architects that the calculations had been made by members of the constructive staff at the Admiralty. Responsible naval officers obviously were the proper persons to assist the court in regard to the actual performances and management of submarines; and on these subjects no more capable officer than Capt. Bacon could have appeared. On the other hand, the work of naval architects is special in character, and cannot be performed satisfactorily by naval officers. The results of calculations and experiments made by constructors should, therefore, have been presented to the court directly by persons who were responsible for them, and whose knowledge of the subject might have been of great assistance. Although the court could not be expected to deal thoroughly with questions relating to buoyancy and stability, such details were necessarily brought into prominence; and their statement and interpretation should have been undertaken by trained naval architects. In the conduct of inquiries into losses of mercantile vessels, technical assessors are associated with legal members of the courts, and technical witnesses appear. The court martial on "A 8" would have been greatly aided if similar technical assistance had been provided from the Admiralty constructive staff, whose members were unconnected with the design of "A 8," and whose ability, as well as impartiality, are undoubted. The primary object of the court martial was fulfilled no doubt, and its finding represents the weight of evidence in the statement that there was no reason "to anticipate danger in running the boat trimmed as at starting, as it appears to have been considered impossible for her to dive under these conditions." It is certain also that if the engines had been stopped at an early period danger would have been averted; and the expression of regret is natural that the officer in "command did not stop the engines sooner when he realized that his repeated orders to put the diving rudders up had no effect." A study of the evidence given by Lieut. Candy indicates, however, that his suspicion of danger was awakened only immediately before the final plunge, and that he took action at once with the intention to stop the engines. His statement as to the suddenness of the final plunge is corroborated by lookers-on in other vessels, and it is clear that the previous sinkage of the bow and rise of the stern were very gradual as the speed was increased. The acquittal of Lieut. Candy is universally approved.

As to the cause of foundering, the finding is that it was due "to water getting in through the open conning tower"—which is unquestionable, so far as the final catastrophe is concerned. Further, it is stated that—

"The buoyancy and trim (at starting) appeared to have altered from some unexplained cause, such as the movement of weights forward, possibly the admission of water or free-water. There is no evidence to show which way the diving rudders were put, although repeated orders were given to put them up. They may, however, have been put inadvertently the opposite way to that actually intended."

In the last passage the court obviously referred to the movement of the rudders when Lieut. Candy gave his first orders, as the rudders were found "hard-up" by the divers, indicating that Lieut. Candy's last order was obeyed. As to the movement of weights forward, the evidence proved that on the worst possible hypothesis only a trifling change of trim could have been produced thereby. In regard to the entry of water forward it has been shown above that there is no evidence whatever of leakage having taken place, except through the crevice surrounding a loose rivet in the petrol tank forward, which was only 150 gallons short of being full. Capt. Lees dismissed this possibility as unimportant and was right in so doing.

No doubt Capt. Bacon's inference that there must have been only 3½ tons reserve of buoyancy before "A 8" could dive, and that if 2½ tons of water had entered forward the trim would have been changed from four degrees by the stern to a small inclination by the bow, had great weight with the court. This inference deserved full consideration, but it requires absolute experimental proof before it can be accepted. Capt. Lees clearly did not accept it as proven or even probable; and on this point his authority is equal to that of Capt. Bacon. Lieutenant Addison's evidence (as indicated above) does not confirm its accuracy. Moreover, at the time of the court martial, no model experiments had been made with the identical form of "A 8," so that experimental proof could not be cited in support of the view. So far as the writer can form an opinion on the established and published facts, it is quite possible that, under the influence of her horizontal rudders, starting with a reserve of buoyancy of six tons and a trim of four degrees by the stern, "A 8" may be made to dive at a speed of ten knots. This is a question that can readily be set at rest by direct experiment either on "A 8" or a sister vessel without any risk of loss of life or property; and such a full-scale experiment is most important as it can be compared with the results of model experiments. In the conduct of these trials and in the analysis of the results, it is in the highest degree desirable that naval architects should take a leading part, and the conclusions derivable from this investigation ought to be of great value in the preparation of future designs for submarines.

One conclusion from the accident to "A8" will command universal agreement. It is imperative, when a submarine is proceeding at the surface, that she shall

* London Times Engineering Supplement. The previous instalments have appeared in SUPPLEMENTS Nos. 1536, 1537, 1538, 1550, 1555, 1556.

possess her maximum possible reserve of buoyancy. In the case of "A8" only about one-half of that maximum was retained; and her conditions were consequently much less satisfactory than they might have been in regard to stability and propulsion; indeed, they were probably such as conduced largely to the disaster, although previous experience had not indicated the fact. Consequently it is satisfactory to know that orders have been given by the Admiralty in that sense, for the guidance of officers in command of submarines.

The tendency to increase the reserve of buoyancy in recent designs, both French and English, has been noted in previous articles and its advantages have been illustrated. There is no difficulty in associating forms which give considerable stability and buoyancy at the surface with the capacity to dive and to withstand external pressure. Necessarily this system involves an increase of "wetted surface" when submerged, and consequently an increase of engine power for a given speed. Capt. Bacon is of opinion that "no object exists in reducing the efficiency of the boats from the fighting point of view by increasing the surface reserve of buoyancy unnecessarily, and so decreasing their speed when submerged." He asserts, and the contention is sound in principle, that the fighting capacity of submarines ought not to be sacrificed to unreasonable provisions for increasing safety. It may be doubted, however, if high speed when submerged is of primary importance to fighting efficiency, and it has been shown that increase in that speed is necessarily a cause of largely increased risks of reaching excessive depths. Like other matters connected with warship design, this is a case for compromise, and opinions naturally differ as to the best combination of qualities. It is a suggestive fact, however, that the B class of submarines in the royal navy far surpass the A class in freeboard and reserve of buoyancy; and the French submersibles have established themselves as superior to submarines largely because of their greater buoyancy and stability.

Accidents to our submarines have given fresh proofs of the splendid qualities of officers and seamen in the royal navy. Volunteers always far exceed requirements, and no accident has affected the readiness of others to take the place of those who have given their lives in the service. The writer has no desire to exaggerate the dangers incurred, or to do anything that would tend to create suspicion of the safety of our submarines when properly handled. But a careful study of the subject has brought with it the conviction that the risks run are and must be of an exceptional character, demanding the employment of special precautions, as well as the services of highly-trained and disciplined men. He has felt it a duty, therefore, so far as lies in his power, to summarize and analyze facts recorded and to explain underlying principles, in order that points on which doubt or difficulty exists may be indicated clearly, and that nothing may be overlooked, or left without thorough investigation, which can add to the efficiency of submarines and the safety of their crews.

[Continued from SUPPLEMENT No. 1556, page 24930.]

IRON AND STEEL HULL STEAM VESSELS OF THE UNITED STATES.*

By J. H. MORRISON, Author of "History of American Steam Navigation."

THE Secretary of the Navy in 1843 contracted with Joseph Tomlinson, of Pittsburg, Pa., for the construction of an iron-hull steamer for the United States navy, which was named "Alleghany." The vessel was commenced shortly after the contract was made, but on account of several alterations being made during construction the vessel was not finished until 1847. This was the first iron-hull vessel of war built for the United States navy. Her dimensions were: Length on deck 185 feet, on keel 171 feet, beam on deck 33 feet 4 inches, beam at the wheels 25 feet, depth of hold 19 feet, mean draft 13 feet 6 inches; tonnage 989 tons. About all that can be obtained at this day of the structural part of the hull is that the T-iron was 4 x 5 x ½ inch; and the deck beams of L-iron 7 x 4 x ¾ inch. The engines had 60-inch diameter cylinders with 48-inch stroke pistons. There were fitted two Hunter's submerged horizontal paddles, placed amidships, 14 feet 8 inches diameter, with paddles 3 feet 6 inches wide and 2 feet 2 inches long. This vessel was in February, 1847, taken down the Ohio River and Mississippi River to New Orleans, and after a short stay at that place was brought around to Norfolk, Va. She was subsequently sent on a cruise to the South American coast, and from there to the Mediterranean Sea, being gone altogether about two years. During this cruise the inefficiency of the Hunter wheel was clearly demonstrated, her best speed while at sea being 7 miles per hour. After being in service but a short time it was found necessary to strengthen her hull by putting in new frames between the old ones. In 1852-53 the Hunter wheels were removed and a screw propeller substituted, and the old engines altered for driving the propeller; and at the same time a Pirsson surface condenser was fitted. The original cost of the vessel ready for service was $242,595, and the alterations made in changing to a propeller cost the sum of $219,000—a very costly experiment for the public treasury.

In 1852 the Harlan & Hollingsworth Company built for the Philadelphia, Wilmington & Baltimore Railroad Company the iron-hull transfer boat "Maryland," for transferring trains across the Susquehanna River between Havre de Grace and Perryville. This vessel was 224 feet by 36 feet 6 inches by 10 feet 2 inches, with two 40 x 96-inch engines. She continued in that service until a bridge was built at that point, when the vessel was laid up. About 1877 she was sold to the N. Y. & N. E. RR. Company and N. Y. N. H. & H. RR. Co. to transfer the through passenger and freight trains from Boston *via* Morrisania to Jersey City, N. J., and *vice versa*. She was destroyed by fire while lying at Morrisania in 1889. The same year they built the "Richard Stockton" for the Camden & Amboy Railroad Company to run in connection with their railroad, from New York to Amboy. This boat had feathering paddle wheels, and was considered above the average in speed.

Reanie, Neafie & Co., of Philadelphia, Pa., built a few iron-hull boats of a small size prior to 1855, but after that date the number increased, so that of later years they have constructed many iron-hull vessels, some of large tonnage. When R. F. Loper introduced his propeller wheel in 1844 this firm was the first to make the application of the new propelling agency. Then began the propeller contest that lasted for several years.

The Pusey & Jones Company, of Wilmington, Del., commenced building iron-hull steam vessels in 1853, the first being the "Flora McDonald," a small sidewheel vessel for service on the Cape Fear River, North Carolina. Four others were constructed prior to 1861 for domestic service, when they began building for South American waters, and since then have built many steamers for that part of the world, some of good size, both sidewheel and propellers. They subsequently built two steamers for the United States revenue marine, the "Grant," and the "Walter Forward," and two for the United States Fish Commission, the "Fish Hawk" and the "Albatross," the latter a sea-going steamer of 900 tons; and one for the Lighthouse Board, the "Wistaria." They also constructed the "Knickerbocker" and the "Hudson" for Cromwell's line from New York to New Orleans.

The heaviest round iron rolled in this country to the close of 1855 was in that year rolled by the Safe Harbor Works of Reeves, Buck & Co., at Safe Harbor, Pa. Several different-sized bars for piles used in rebuilding of the Brandywine Shoal lighthouse in Delaware Bay, were rolled. Following are the sizes:

5½ inches diameter, 15 feet 6½ inches long, weighing 1,248 pounds.

5½ inches diameter, 24 feet 4 inches long, weighing 1,945 pounds.

6½ inches diameter, 14 feet 5 inches long, weighing 1,617 pounds.

6½ inches diameter, 18 feet 11 inches long, weighing 2,100 pounds.

Iron shipbuilding in the United States is thus spoken of in 1856: "The advantages attending the use of iron as a material for shipbuilding are so many that it is a matter of surprise that up to the present time in this country, they have been almost entirely overlooked. We have on the Delaware a few steamboats where its merits have been appreciated, and the saving by a reduced draft of water in consequence of less weight of hull, is of itself more than sufficient to counterbalance any increased first cost of construction. In addition to this, iron is more lasting. After ten years in a wooden ship, and half that time in a sea steamer, the frames, planking, etc., become so decayed as to be a constant source of expense, and our insurance companies consider eleven years as the *average* duration of timber-built ships. We have but two iron vessels constructed for sea service, the coast survey steamer 'Walker,' and the revenue cutter 'Polk.' These vessels have been in use for eight years, and a recent examination of the former vessel when on the dock did not disclose any symptoms of decay beyond a very slight rust. The bottom plates appear as thick as when first put on, and in fact all that portion of the hull made of iron was in good condition, while the wooden decks and waterways were very nearly worn out. In England the merits of iron are more fully understood, and a wooden vessel there is as rare as an iron one here. Many of the iron shipbuilders are those formerly engaged in timber-built vessels, and in a few years the merchant ships of England will nearly all be of iron. It may be urged that iron is more costly and timber much cheaper here than there. This is true, but yet is not sufficient for the neglect on our part to examine into the matter more fully. Within the last five years the wages of ship carpenters (always in advance of those in England) have advanced. Ship timber of all kinds is now worth more than then, and the price of good timber will be constantly advancing from its increasing scarcity, which has caused for years past the use of inferior material. Copper, which enters largely into the construction of timber-built ships, has in that time advanced twelve cents a pound, or about 50 per cent. While this has been the case with the material used in timber-built vessels, iron has, on the contrary, not advanced, and can at the present time be purchased at a price sufficiently low to enable vessels to be built at a price but little, if any, exceeding the cost of a *first-class* timber-built vessel. But admit that the iron vessel should cost ten or even twenty per cent more than the wooden one, look at the advantages to be gained, viz.:

"*Increased capacity* as to bulk of freight equal to 20 per cent, which, on a ship carrying 5,000 bales of cotton, would make a difference of 1,000 bales, increasing freight money in the same proportion.

"*Safety at sea* from not leaking, and when injured by collision, not sinking, the iron bulkheads preventing this, as in the 'Vesta,' the ship that came in contact with the 'Arctic.'

"*Durability.*—An iron vessel will outlive three wooden ones. Twelve years make no impression on them.

"A timber-built ship has a very great number of vertical and horizontal joints between the planks, where there is no connection, which are filled with oakum to prevent the vessel from leaking, and it is the starting of one of these at sea that causes many a ship to founder, and damages cargo to the amount of many hundreds of thousands of dollars annually. This is an evil inherent in wooden vessels, and nine out of ten suffer in some degree from it every voyage. An iron vessel, on the contrary, has not such a seam in her construction. Every sheet is made to lap its neighbor, and they are firmly riveted together, making the vessel as one piece. The introduction of iron shipbuilding among us would do much toward increasing the consumption of plate iron, and at the same time give to the merchant a better and more profitable vessel."

The greatest defect found in the wooden-hull steamer of this period was the want of watertight bulkheads. After the loss of the Collins line steamer "Arctic," the use of watertight bulkheads began to be much discussed, as the safety of the "Vesta," with which the former collided, proved the worth of watertight compartments in a vessel in case of collision. There were subsequently placed in some wooden-hull steamships iron bulkheads, but these did not always maintain a close joint to the sides of the vessel, the elasticity of the wooden hull being greater than the iron bulkhead.

The first iron-hull steamship for ocean service was the "Champion," built in 1858 by The Harlan & Hollingsworth Co. for Cornelius Vanderbilt. This vessel was a sidewheel vessel of 1,500 tons, and driven by a pair of lever beam engines. She ran from New York to various coastwise ports south of that city for many years. The same builders constructed in the same year a propeller named "Ellen S. Terry," of 400 tons, for coastwise service for Hartford, Conn., parties. This vessel was an early iron-hull propeller in the merchant service, having all the improvements of the day, and was looked upon as the advanced type of freighting vessel of those times. She proved to be a good investment for the owners. Her dimensions of hull were 142 feet by 23 feet by 14 feet, with a condensing engine of 28 inches by 26 inches stroke. The next year they built the "Benj. Deford" and the "S. R. Spaulding," both sidewheel steamships of 1,400 tons each, for the Merchants and Miners Transportation Company. These vessels were subsequently known as the "San Salvador" and "San Jacinto" when on the New York and Savannah line.

From the time of the building of the "Iron Witch" in 1845 there appear to have been but few iron hulls constructed at New York or the vicinity for several years, the shipyards on the Delaware River having all the work in that line without any break up to about 1860, except it were a few small sidewheel steamboats for South America, and two steamers for coastwise service. These were spasmodic attempts of the marine engine works at New York to compete with the Delaware River yards, that in the end were a failure. The latter yards being close to the iron mills in Pennsylvania, their freight expenses being comparatively small for the delivery of their iron, and the rate of wages being lower also than at New York, was more than the builders at the latter city could contend against in competition for the business.

In 1847 there was built at the works of Mott & Ayres, foot of West Twenty-fifth Street, New York, two iron-hull sidewheel steamboats for the Magdalena River in New Granada, S. A. They were each 150 x 25 x 6, with two high-pressure engines, each 18 inches by 6 feet stroke. They were named "Magdalena" and "Santa Marta." In 1853 and 1854 there was also built at the same works four iron-hull sidewheel steamboats for the Orinoco River in South America. Two of these hulls were shipped in sections, the other two vessels finished complete, and sailed for their destination under their own steam. They were each about 150 feet long.

Boardman, Holbrook & Co., Neptune Iron Works, of New York, completed in July, 1857, an iron hull of 175 x 32 x 8 for the Magdalena River. This vessel sailed under canvas, as the machinery was already in South America—being that of the "Santa Marta" of 1847—and was especially prepared for the voyage. Her name was also "Santa Marta." There were four transverse bulkheads in the vessel with a longitudinal bulkhead built on the main keelson and carried up to the under side of the deck beams, thus making ten watertight compartments.

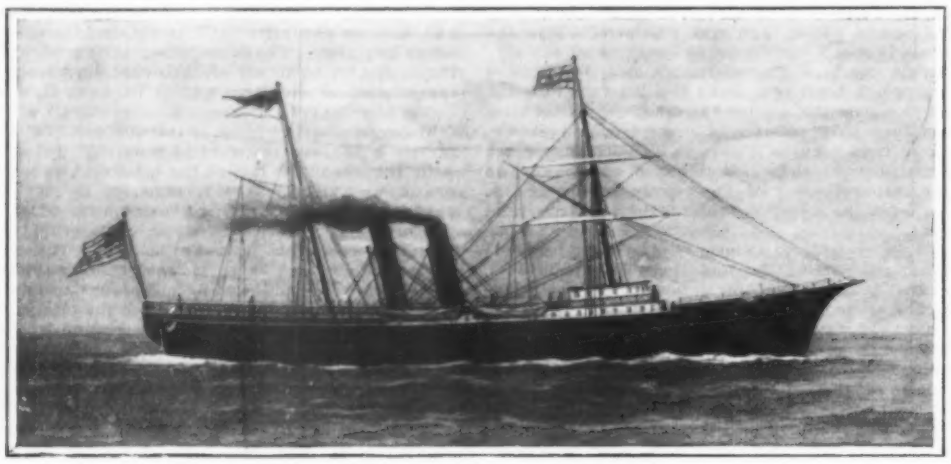
In the same year Birkbeck & Hodges, marine engine builders, of New York city, built at Williamsburg, opposite New York, in the shipyard of Lawrence & Foulks, the iron hull of the steamboat "Virginia" for the Mississippi Sound Company, of 230 x 35 x 9 feet. The engine was of 48 inches by 12 feet stroke, with two boilers for a working pressure of 35 pounds that were built at their works. This vessel was in service at New Orleans, La. Before this vessel had been ten months in use, and while lying at her wharf, she was totally wrecked by the explosion of one of her boilers, causing the death of seven of her crew. The stop valve upon the branch steam pipe to this boiler was closed, and the safety-valve attachment entangled, misleading the engineers as to the steam pressure, resulting in an overpressure of steam.

The next year Boardman, Holbrook & Co. built another small sidewheel iron-hull steamboat. This was for the Louisiana-Tehuantepec Company, and named "Serchil," for service in Central America. The dimensions of the vessel were 140 feet by 34 feet by 5½ feet, with one longitudinal bulkhead running the entire length of the vessel, which also had three cross bulkheads. The motive power consisted of two inclined engines having cylinders of 18 inches bore and 6 feet stroke.

Samuel Sneeden & Co. in September, 1857, completed

*Specially prepared for the SCIENTIFIC AMERICAN SUPPLEMENT.

at their yard in Greenpoint, New York, the iron-hull steamer "Alabama." This vessel was built for James L. Day, on account of the Lake Pontchartrain Steamboat Line in the Gulf of Mexico, and was the first iron-hull vessel built at the yard of what later became known as the Continental Iron Works, and where the "Monitor" was constructed by T. F. Rowland, who became the junior member of the firm just after the



THE "HAVANA" OF 1863.

commencement of the work on the "Alabama." The dimensions of the hull of this vessel were 225 x 32 x 9; frames 3½ x 3½ inches; plating 5-16 inch to ½ inch. Motive power was a beam engine by the Morgan Iron Works, having a 50-inch cylinder by 10-foot stroke. In the same year the firm built for A. Poppenhusen and others the sidewheel steamboat "Flushing," having a 3 x 10-foot beam engine built by the Morgan Iron Works. This vessel ran to Flushing, N. Y., until purchased by the United States government in July, 1861, when she was sent south. After a few years' service she was wrecked, but was afterward raised, sent north, where she had a new iron bottom fitted to her hull, and returned south, where she was worn out. The Continental Iron Works now had their yard for several years steadily employed in constructing the monitor type of naval vessels for the United States navy. In 1871 they built for the Union Ferry Company of New York two iron-hull ferryboats, the "Fulton" and the "Farragut." They were fitted each with the inclined engine, so long in use on these ferries. In 1884 they constructed two steel-hull ferryboats for the same company, having beam engines, and named "Atlantic" and "Brooklyn."

In 1859 C. H. Delamater & Co. built the screw steamer "Matanzas" for the New York and Cuba trade. This vessel was 205 feet by 29 feet 6 inches by 20 feet 9 inches with a loaded draft of 13 feet; frames 3½ x 3½ x ⅝ inch; plating ⅜ to ½ inch; double riveted, four athwartship bulkheads. This was the largest iron-hull screw propeller built up to that time in this country.

The next year the Novelty Iron Works built an iron-hull propeller from the design of John Baird, engineer, for H. B. Cromwell & Co. for their Wilmington, N. C., trade, which was named "North Carolina." The dimensions were 172 x 29 x 13 feet with a draft of 9 feet loaded, frames 4 x 3 x ⅝ inch, and plating ½ inch. There were four watertight bulkheads, single riveted throughout. The motive power was a vertical direct-acting condensing engine 42 x 42 inches. The vessel left New York on her first voyage and arrived at Wilmington, N. C., on January 30, 1861, just prior to the outbreak of the civil war, was seized, or otherwise detained there by her southern owners, became a blockade runner, was captured on one of the ventures by the blockade squadron, and subsequently sold by the government and her name changed to "Gulf Stream." She was lengthened about 40 feet in 1868.

In 1856, the iron rolling mills producing most of the plate iron and sheet iron of the country were located mainly about Philadelphia, Pa. There were twenty-five in east Pennsylvania, two at Jersey City, N. J., one at Baltimore, Md., fourteen at Pittsburg, Pa., with one at Portsmouth and one at Cincinnati, Ohio.

Hogg & Delamater built for R. B. Forbes, of Boston, Mass., three small iron-hull steamboats that were shipped to foreign waters at an early date: The "Fire Fly," a screw propeller built in 1846, of 20 tons, that was sent at first to China, and afterward from China during the gold fever to California. The "Mist," built in 1848, of 40 tons, with Ericsson engine, went to San Francisco on bark "Somerset." In 1856 one of 75 tons, no name, sidewheeler, went to China on brig "Rolling Wave."

Boston, Mass.—After the building of the "R. B. Forbes," in 1845, at Boston, Mass., before referred to, there were very few iron-hull vessels built for the merchant service in that locality for several years, though there were built there during the civil war twelve monitors and iron-hull tugboats by private parties for government service. There were in papers treating on iron shipbuilding at Boston, statements made of the construction of the iron-hull revenue steamer "Saranac" by Jabez Coney in 1845. This vessel was a *naval* steamer, built *of wood* at the Portsmouth navy yard in 1848, with engines constructed by Jabez Coney. The revenue steamer referred to is more probably the "McLane," already described. In 1858 an iron-hull screw steam yacht was built at Boston for the Pasha of Egypt and named "Voyageur de la Mar." The hull was constructed by Holden & Gallagher, with dimensions of 216 feet by 36 feet 7 inches by 21 feet; floors 6 x 3 inches, with five watertight bulkheads. The motive power was furnished by the Atlantic Steam Engine Works, and consisted of two oscillating engines, each having cylinders 54 inches diameter by 36 inches stroke. The vessel was not a success, on account of insufficient boiler power and too small engines. About the same time the Atlantic S. E. Works built a small sidewheel steamboat of 100 tons named "Argentina," for the survey of the river La Platte in South America; also a small iron steamer of 22 tons that was taken out on the deck of a sailing vessel to the same river. The same builders the next year built another of 70 tons that was sent to China. They also built in 1860 the screw steamer "Pembroke" of 113 feet 6 inches by 24 feet by 9 feet 5 inches, with an engine of 26 x 36 inches. The vessel was sold for a coast guard to the State of Massachusetts, and next year was purchased by R. B. Forbes, who sent the vessel to China, where she was afterward sold. They also constructed the same year four small river steamboats of about 60 feet in length each with side wheels that were sent to the East Indies.

Harrison Loring, of South Boston, in 1858 built the propeller "Sestos" with dimensions of 146 feet 9 inches by 25 feet 8 inches by 14 feet 8 inches, having two oscillating engines each 38 x 32 inches, and three watertight compartments; and the next year the "Contest," of the same general dimensions, both of which were sent to the Hoogly River in India. The same builder in 1860 constructed two screw steamships, the "South Carolina" and the "Massachusetts," each of 1,200 tons, that were afterward known as the "Juniata," and the "Crescent City." They were purchased by the Navy Department during the war, and fitted for the blockade squadron. In 1862 he also built two larger screw steamships, the "Mississippi" and the "Merrimac." They ran for several years on the New York and Brazil line, and also to New Orleans, La.

In 1868 the Atlantic S. E. Works built the "William Lawrence" for the Boston and Baltimore line, of about the same tonnage as the "South Carolina."

Of the government vessels built at Boston, Mass., during the years of the rebellion, Harrison Loring constructed the double-ender sidewheel "Winnipeg"; Donald McKay one double-ender and sidewheel, also the "Nanset," a monitor of 700 tons; Nathaniel McKay the monitor "Squando"; Atlantic S. E. Works monitors "Casco" and "Shawnee." The monitors "Chimo," "Wassuc," and the "Suncook" were built there during the same period by other builders.

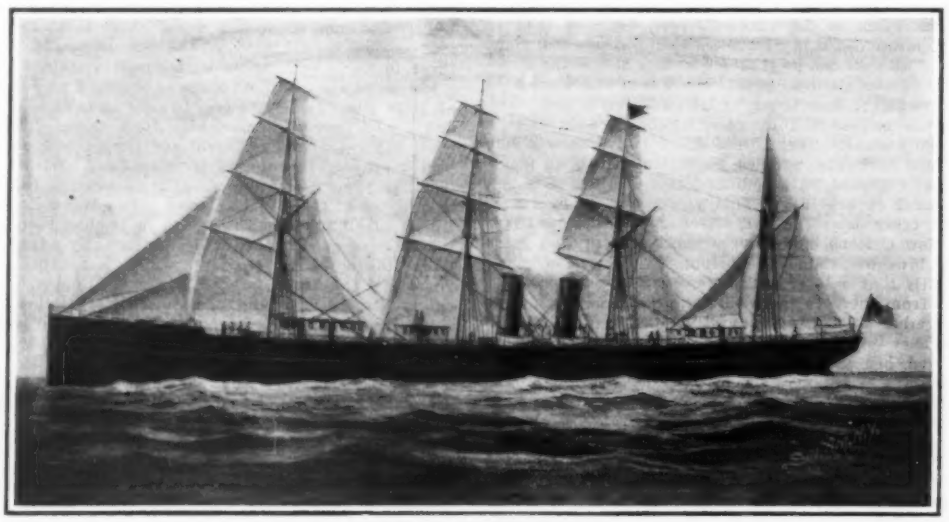
The Atlantic S. E. Works have built of later years the steel-hull steam yacht "Shearwater," 250 tons, launched May, 1887; the "Unguowa," the "Jathniel," and the "Wild Duck." They also built the revenue cutter "Daniel Manning" in 1897. A number of other steel-hull boats also belong to this period.

III. MODERN SHIPBUILDING PLANTS ON THE ATLANTIC COAST.

The greatest development of our merchant marine, at an early period, was during the decade from 1845 to 1855, with the opening of our coastwise lines with steamships, the building of our large clipper ships, the establishment of our transatlantic steamship lines, and with the hundreds of sailing vessels that were built for service to the Pacific coast during the gold excitement. These were high-water days for our shipbuilders, and advantage was taken of the large demand for vessels. Vast improvements were made in the construction of the vessels, both steam and sail, in a few years, and our builders were acknowledged to be the best constructors of wooden-hull vessels of all the maritime nations. There came at the end of the decade many changes, commercial and political, that affected the further development of our merchant marine, and taken in connection with the severe financial panic of 1857 in the United States, proved the beginning of the end of wooden shipbuilding in this country. Then followed a depression in this business, broken for the first period of the civil war, when an increased demand for steam vessels gave it renewed activity for the time being. After 1865 the condition of our merchant marine was worse than that preceding the war. It was now that the question began to be discussed again of wood against iron, for during the 1861 to 1865 period there was no time for discussion of iron hulls, except so far as it related to naval vessels.

When the attempt was made to regain our lost trade on the ocean about 1868 with our wooden-hull sidewheel steamships, it was found that we had lost much ground in the last six years. There had grown up in that time the iron-hull screw steamer until it was no longer an experiment, having proved itself a better vessel in every way than the wooden-hull sidewheeler, having a lower rate of insurance, more economical in operation, and a larger carrier for same size of vessel. When the discussion in commercial circles a few years later turned on the subject of the restoration of the American merchant marine, the iron-hull vessel received much attention. The old discussion of wood versus iron vessels again waxed warm and might have lasted longer than it did, but the compound propeller engine was then in its first stage, and, with its economy of fuel, the comparatively small space it occupied, and the good service obtained from this type of vessel, it soon broke down the barrier of prejudice there was existing among the owners of steam vessels against iron hulls, so that in a few years the days of the wooden-hull vessel were seen to be near a close. In the United States at this period, it was the combination of the iron hull and the compound engine that figured in the rebuilding of our merchant marine, that was employed mainly to ports of the West Indies, South America, and on our coastwise lines, with our large internal steam navigation.

Up to 1860 the building of iron-hull steam vessels had been mainly on the Atlantic coast. The shipbuilding plants at that time, that were equipped with tools of a size to construct a vessel of 500 tons and over, were confined to three on the Delaware River, two at New York, and one at Boston, Mass. Most of these builders were able at the time to contract for the construction of a vessel, with her machinery, within their own plant. The call of the government within a few years for iron-hull vessels in the emergency of war, caused the placing of heavier tools and machinery in the large shipbuilding plants of the period, to produce the heavier class of work demanded at the time. These additions, made for an emergency, became of great value, when iron shipbuilding began to assume a more definite form in the next decade, to those remaining



"CITY OF PEKING," 1874.

in the business. Prior to this change, however, there had been a leveling process going on. Four or more of our largest marine engine works, some that had built iron-hull vessels, were closed up, and the owners retired from business. With their retirement came the establishment of new iron shipbuilding yards, equipped with more modern tools, and having facilities within themselves to build a vessel entire; to equip

and furnish them ready for service and operation. This was the extension of an important industry in this country, and at an opportune moment, for our merchant marine was then in that condition that almost any improvement would be of an advantage over the wooden-hull sidewheeler.

The Delaware River Iron Shipbuilding Company at Chester, Pa., was established in 1871. They purchased the plant previously owned and operated since about 1862 by Reaney, Son & Archbold, who had constructed several iron-hull steam vessels as well as marine engines at these works. John Roach, who became the proprietor under the new order of things, at once began the improvement of the property by the addition of many large and new buildings, in which were placed improved machinery for the construction of large iron vessels. The first vessel launched from this yard was the steamship "City of San Antonio" on April 5, 1872, for the Mallory line. This was followed by two propellers for the Pacific Mail Steamship Company, the "Colon," and the "Colima;" two ferryboats; and the "City of Waco." During 1874 they built eight ocean steamships, among which were the "City of Peking" and "City of Tokio," of over 5,000 tons each, for the Pacific Mail Steamship Company. In 1875 they completed four vessels, all over 2,500 tons each. In ten years after this date they built fifty-two merchant steam vessels, ranging from 900 to 3,500 tons each, among them being the fleet of the Ocean Steamship Company, Alexandre's line to Havana, Cuba, those of the Old Dominion Steamship Company, three sidewheel boats for the Iron Steamboat Company of New York, the "Pilgrim" for the Fall River line, and several large steam yachts. In 1886 they completed the naval steamers "Chicago," "Atlanta," "Boston," and "Dolphin."

William Cramp, of Philadelphia, Pa., was a builder of wooden vessels up to 1863, when he entered into a contract with Merrick & Sons for the woodwork in the building of a light-draft monitor, the "Yazoo," that was broken up in 1874. In 1865 he equipped his yard for building iron vessels, and the next year he built two iron-hull iceboats for the city of Philadelphia, and with the exception of a few small vessels did not build any of iron until 1870, when William Cramp & Sons built for Thomas Clyde the steamer "Clyde," and in 1872 the "George W. Clyde," having the first compound engine built for a merchant vessel on the Delaware River, and that was successful. J. Shields Wilson was at this time the superintending engineer of the works. In 1872 and 1873 they built the four steamships for the American line from Philadelphia to Liverpool, each over 3,000 tons. They have built many large steamers for the Pacific coast, many large steam yachts, several fine large freight steamers for Morgan's line, and battleships and cruisers for the United States government that have received much notice.

During 1863 the Navy Department made contracts for the construction of seven double-ended gunboats having iron hulls of 255 x 35 x 20 feet, and fitted with inclined engines of 60 inches by 9 feet. These vessels were not completed when the war was closed. Two of them were sold in 1869 to the Clyde Company—one named the "Minnesota"—and finished for the Charleston line. They were named "Georgia" and "South Carolina" by the company.

The Harlan & Hollingsworth Company was established in 1836 under the firm name of Betts, Pusey & Harlan, as car builders. In 1841 Samuel W. Pusey retired from the firm, his interest being taken by Elijah Hollingsworth, and Mahlon Betts retiring from the firm in 1849, when the firm name became Harlan & Hollingsworth, as it has been known of later years. It was not until 1844 that they constructed the "Bangor," their first steamer of iron. They had built two smaller vessels the same year.

During the first fifty years of their business organization they had constructed seventy screw steamers and one hundred and thirteen side-wheel steamers, all of iron. Of later years they have constructed many large steam yachts, several of the largest and fastest sound and river passenger steamboats, as well as many of our large coasting steamships. They can be placed as the oldest iron-hull shipbuilding concern in this country now in operation.

The first iron shipbuilding yard at Baltimore, Md., was that of William T. Malster, afterward Malster & Reaney, who commenced operations in 1876. There had been at irregular intervals iron shipbuilding by the Winans brothers, on their experimental vessels prior to 1860, and several composite vessels constructed by Woodall & Co., yet there was no regular plant devoted to iron shipbuilding prior to the Columbian Iron Works of W. T. Malster. In the first five years of their business they had built three steam tugs, a sidewheel iceboat 200 feet long, the steamboat "Enoch Pratt" for Chesapeake Bay service, and two sidewheel lighthouse tenders, the "Holly" and the "Jessamine." In the spring of 1888 they completed two of the largest steel-hull ferryboats then built for New York waters, the "Erastus Wiman," and the "Robert Garrett." In 1890 they built the first iron-hull tank steamer in the United States. It was used for transporting oil in bulk by the Standard Oil Company.

Ward, Stanton & Co., of Newburg, N. Y., began the work of iron shipbuilding in 1876, their first vessel being a steam lighter for Central America. They subsequently constructed several large steam yachts, the "Polynia," "Henrietta," "Radha," and "Namouna," besides several ferryboats and many large tugs. About 1885 this plant passed into the possession of James Bigler, who did considerable work until 1889, when the machinery and tools of the plant were sold to the Chesapeake Dry Dock Company at Newport News, Va. In 1890 Thomas Marvel & Co. became the proprietors of the drydock at Newburg lately operated by Ward, Stanton & Co., and with additional facilities for the prosecution of the business, have conducted an iron shipyard that has produced many medium-size vessels, for passenger, ferry, and freight service, of the first class.

The American Shipbuilding Company, of Philadelphia, Pa., was established in 1883. H. H. Gorringe, formerly of the United States navy, was president of the company, and J. F. Tams secretary and treasurer. This company built a few steam vessels, and one large sailing vessel, and a few small sailing vessels, when financial difficulties overcame them, in three or four years, and the business was closed up.

The Bath Iron Works, of Bath, Me., was established in 1883 as a marine engine works, but it was not until 1890 that the plant was increased to construct iron and steel vessels. Their first contract was for the construction of two gunboats for the Navy Department, the "Castine" and the "Machias," in April, 1890, followed the next year by a contract for building the armored ram "Katahdin." The largest merchant vessel they have built is the famous steel-hull Long Island Sound steamboat "City of Lowell," constructed in 1894.

The Crescent Shipyard, at Elizabethport, N. J., was opened in 1890. They have built the hull of the ferryboat "Cincinnati" for the Jersey City ferry of the Pennsylvania Railroad Company; the practice cruiser "Bancroft" for the United States navy; and the lighthouse tender "Maple," and many large steel-hull tugboats. In 1894 the works passed into the possession of Lewis Nixon, who had lately been superintendent of construction at William Cramp Ship and Engine Building Company. Since then he has built many large steam yachts, several torpedo boats for the United States navy, as well as one monitor for coast defense, with other work of a similar character up to the time of the financial difficulties in the United States Shipbuilding Company in 1903.

John H. Dialogue was one of the members of the National Iron Armor and Shipbuilding Company that commenced business in Camden, N. J., about 1862. The first vessel they built was the propeller "Lookout," of 35 tons, for W. P. Clyde. This company continued in business not more than two years when financial troubles overcame them, and their business affairs were closed up in a short time. The firm of Wilcox & Whiting came into possession of the plant. Mr. Dialogue shortly after became a sub-contractor under A. & W. Denmead & Son at Baltimore, Md., in the construction of the monitor "Waxsaw," of 614 tons. About 1872 the firm of Wood & Dialogue, River Iron Works, was formed and their plant located at Kaighans Point, Camden, N. J. In that year the propeller "Frank G. Fowler," of 48 tons, was built. A few years later Mr. Dialogue succeeded to the business of the firm by the death of his partner. The specialty of this yard has been the construction of iron-hull propeller tugboats of large size. He was among the first to adopt the compound marine engine and Scotch boiler in his tugboats, as well as in larger vessels. J. H. Dialogue, Jr., succeeded to the business on the death of his father about twelve years ago.

The plant at Newport News, Va., was first organized as the Chesapeake Dry Dock and Construction Company in July, 1889. Controlling the Simpson drydock in the immediate vicinity, the company was reorganized in April, 1890, as the Newport News Shipbuilding and Dry Dock Company. Their first vessels were in 1891, the tugs "El Toro" and the "Dorothy," the latter having quadruple-expansion engines; and in 1892 the Morgan line propellers "El Norte" and "El Cid." They have since built many large coasting steamships, as well as several battleships and cruisers for the United States navy.

Among the largest of the more modern plants on the Atlantic coast is the Maryland Steel Company at Sparrows Point, Md. The shipyard of this company was opened in February, 1890, and during the next four years built the steamers and steamships "Lancaster," "Alabama," "Gloucester," and "Tivoli." The yard was then closed on account of the depression in the shipbuilding industry until 1898, when the "Chester W. Chapin," for the New York and New Haven line, was taken in hand during the next year, which was succeeded by three torpedo-boat destroyers, two cargo steamers for the Boston Towboat Company, and in 1902 by the "Shawmut" and the "Tremont," of 9,600 tons each, for the Boston Steamship Company.

The last metal-hull vessel built at New York city was the "New Yorker." This steel-hull vessel was built for the New York Fire Department in 1890, at the Johnson Foundry and Machine Company at 118th Street and Harlem River.

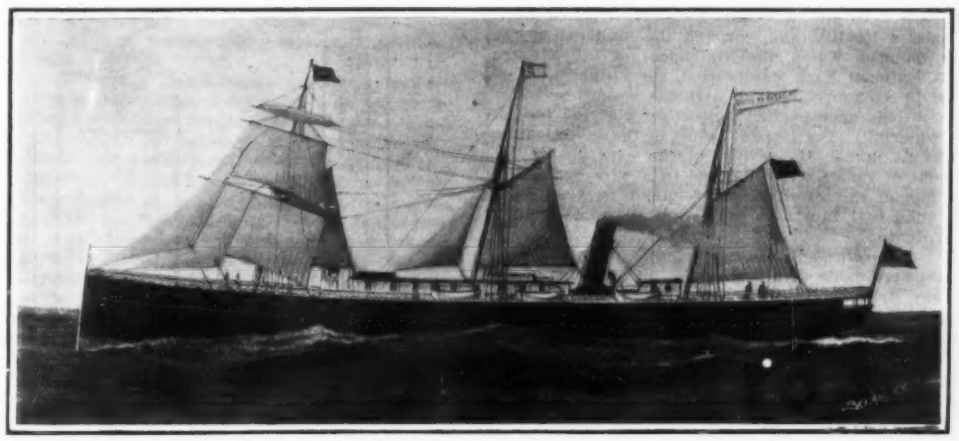
The New York Shipbuilding Company at Camden, N. J., was organized in March, 1900, and the first vessel launched from this yard was the "M. S. Dollar" on May 4, 1901, for the Robert Dollar Company, of San Francisco, Cal.

The United States Shipbuilding Company was incorporated June 17, 1902, through the consolidation of the Samuel L. Moore Son & Co., the Crescent Shipyard, the Union Iron Works, San Francisco, Cal.; Bath Iron Works, Hyde Windlass Company; Eastern Shipbuilding Company; Harlan & Hollingsworth Company, Canda Manufacturing Company.

The Fore River Ship and Engine Company at Quincy, Mass., was fitted for building steel vessels in 1898. Their first contract was for light vessel No. 72, followed by torpedo destroyers "Lawrence" and "McDonough." They also built later the cruiser "Des Moines" and the battleships "New Jersey" and "Rhode Island," with passenger and freight boats for Long Island Sound service in 1904.

The Eastern Shipbuilding Company at New London, Ct., was organized in 1900. The Burlee Dry Dock Company at Staten Island, N. Y., was established about 1898 for iron shipbuilding.

(To be continued.)



"GEORGE W. CLYDE," 1872.

BRONZE COLORING.

FOR many years, says Dr. Steinau in the Farben Zeitung, the most variegated shades of color, the so-called annealing colors, have been produced in the fire with the aid of certain reagents, in the manufacture of bronzes. But the so-called patent bronzes are also very popular. By patent bronzes are meant products colored by means of aniline dyes. They have hitherto been used in the manufacture of toys and "de luxe" or fancy paper, but makers of wall or stained paper have recently given their attention to these products. Wall—or so-called *Moiré*—paper prepared with these dyes furnishes covers or prints of the most lovely silken gloss with a peculiar double color effect, in which the metallic brilliancy characteristic of bronze combines with the shades of the tar pigments used. Very beautiful reliefs giving rise to the most charming play of colors in perpendicular or laterally reflected light are produced by pressing the paper lengths or web painted with aniline-bronze dyes. The brass brocade and tin bronzes serve as bases for the aniline dyes; of the tar pigments, only basic aniline dyes soluble in alcohol are used. In coloring the pulverized bronze, care must be taken that the latter is as free as possible from organic fats. Tar dyes should be dissolved in as concentrated a form as possible in alcohol and stirred with the bronze, the pigment being then fixed on the vehicle with an alcoholic solution of tannin. The patent bronze is then dried by allowing the alcohol to evaporate. This kind of coloring is a purely mechanical one, as the tar dyes do not by any means combine with the metallic bronze, as is the case with pigments in which hydrate of alumina is used. A coating of aniline bronze of this kind is therefore very sensitive to moisture, unless spread over the paper surface with a suitable protective binding medium or protected by a transparent coat of varnish, which of course must not interfere with the special color effect.

The introduction of agricultural instruction into the primary schools is being more widely discussed than ever before at meetings of teachers and farmers. The success of the nature study and school garden movement in a considerable number of city and country schools has led to a demand for the more formal teaching of elementary agriculture in the higher grades of the rural schools. The National Educational Association, State superintendents of public instruction, officers of agricultural colleges, as well as a number of other organizations and numerous individuals in various official positions, have of late interested themselves in the introduction of elementary agriculture and gardening in these schools. The National Educational Association now has a special committee of educators of national repute considering this subject.

INDUCED RADIOACTIVITY EXCITED IN AIR AT THE FOOT OF WATERFALLS.*

By J. C. McLENNAN, B.A., PH.D., Associate Professor of Physics, University of Toronto.

I. INTRODUCTION.—The fine drops of spray into which water is broken on passing over waterfalls were found by Lenard† to communicate, on striking the wet rocks at the foot of a fall, a negative charge of electricity to the surrounding air and a positive charge to the water. From a number of laboratory experiments with jets impinging on metal plates he obtained the same results with pure water, but found that the presence of any impurity greatly lessened the effect. With certain solutions—notably sodium chloride in water—the action weakened with an increase in the strength of the solution, and was finally reversed, a positive charge being communicated to the air and a negative charge to the liquid. The splashing of rain he found imparted a negative electrification to the surrounding air, while the breaking of waves on the sea shore electrified it positively. The experiments of J. J. Thomson‡ and of Elster and Geitel§ have confirmed these observations, and, while showing that the sign and the amount of the electrification imparted varied both with the liquid and with the gas in which the splashing occurred, yet the splashing of pure water in air always gave a negative electrification.

A little over a year ago Elster and Geitel‖ found that if a negatively electrified wire were exposed for some hours in the open air or in a very large room, it became temporarily radioactive. Since then a number of observations have been made upon this effect, and the consensus of opinion appears to be that it is due to the presence in the atmosphere of some peculiar constituent similar to the emanation from thorium, which has been shown by Rutherford¶ to induce radioactivity in any body with which it comes in contact, especially when that body is negatively electrified.

The difficulty of determining and of regulating the atmospheric conditions for observations upon this excited or induced radioactivity suggested the desirability of resorting, for purposes of experiment, to a locality where exceptional electrical conditions were known to exist permanently in the atmosphere. Niagara Falls, according to Lenard's results, is pre-eminently such a locality, and, through the kindness of the Hon. Thomas Walsh, Superintendent of the Niagara Falls National Park Reservation, the author was enabled in September last to carry out a short series of observations upon excited radioactivity at the foot of the waterfall. The general result of the investigation was that during the course of the experiments the amount of radioactivity induced in a wire exposed at the foot of the waterfall was found to be very much less than that in a wire exposed in the same manner in Toronto.

II. *Apparatus.*—In these observations the measurements were made with a quadrant electrometer of the Mascart type as constructed by Carpentier. The silk suspension in the original apparatus was replaced by a phosphor bronze strip less than 0.025 millimeter in thickness, which was attached at its upper end to an ebonite rod to secure insulation. The needle was kept charged by a battery of small storage cells similar to those installed in the Reichsanstalt and the deflections were measured by the movement of the image of an incandescent lamp filament upon a transparent scale placed at a distance of one meter from the electrometer.

With a potential of 480 volts applied to the needle, the sensibility of the instrument was such as to produce a deflection of 1,000 millimeters on the scale for a potential difference of one volt between the quadrants. In measuring the induced radioactivity, bare copper wire No. 24 was exposed in the open air by means of specially constructed insulating supports (Fig. 1), attached to a series of bamboo poles erected at convenient distances. The wire was charged by a small Toepler Holtz electrical machine driven by a water motor, which maintained a potential of from eight to ten thousand volts.

The insulator shown in Fig. 1 consisted of a brass tube about 20 centimeters long, closed at one end and having a bell-shaped opening at the other. Into this tube an ebonite rod was screwed which could be easily removed when it was necessary to renew its surface. Hooks fastened to the tube and to the ebonite rod provided for the support of the insulator and the suspension of the wire. In the experiments at the foot of the waterfall it was found that, with these insulators, a wire could easily be maintained at a potential of 10,000 volts for hours, even in a drenching spray.

The exposed wire was tested for induced radioactivity by means of the apparatus shown in Fig. 2. *A* was a galvanized iron cylinder about 30 centimeters high and 20 centimeters in diameter, resting on an insulated platform and having a movable cover provided with a flanged opening into which was fitted an ebonite plug about five centimeters in diameter. A brass tube, *C*, was passed through this plug and into it a second ebonite plug was tightly fitted. This second plug carried a brass rod, *D*, from which *B*, a brass reel, was suspended, and on this reel the wire to be tested was wound. The brass tube, *C*, which was earthed throughout the measurements, served as a guard ring and prevented any leak from the vessel *A* to the rod *D* across the ebonite plugs.

The saturation current due to spontaneous ionization of the air in the vessel having been first determined by connecting the supporting rod *D* to the electrometer in the usual way and applying a potential of 100 volts to *A*, the exposed wire was then wound on the reel, inserted in the vessel, and the saturation current again ascertained. Any increase observed in the ionization current was taken as a measure of the radioactivity induced in the exposed wire.

As it was impossible, in setting up the apparatus, in two different localities, to be certain that it was of exactly the same sensibility, a standard of ionization was deemed necessary for purposes of comparison. A radioactive substance which the writer had in his laboratory at the time of making the experiments was chosen, and a small quantity in a glass phial being found to give a constant ionization current when placed in a given position in the chamber *A*, this current was adopted as a standard and the ionization currents measured in the various tests were expressed in terms of it.

III. *Experiments.*—Both before proceeding to Niagara and after returning, a series of exposures was made in the quadrangle of the University at Toronto. Copper wires, approximately 30 meters long, were exposed for periods of two hours at a potential of 8,000 to 10,000 volts on a number of days. After a wire had been exposed it was placed in the ionization chamber, the saturation current measured and its radioactivity, thus ascertained, was expressed in terms of the standard radioactive substance. The resulting values, taking the standard saturation current as unity, showed considerable variation in the amount of radioactivity excited, the highest value observed being 1.75 and the lowest 0.6. The intermediate values ranged between these limits but were quite irregular and seemed to depend more upon the existence of wind and its velocity than other changes in the weather. The occurrence of showers did not exert a noticeable effect on the amount of radioactivity excited. It was frequently observed that exposures made in the morning gave greater induced radioactivity than those in the afternoon, but that exposures made after sunset gave values

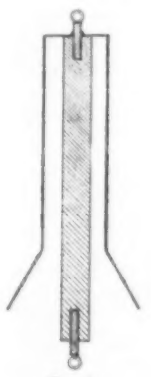


Fig. 1

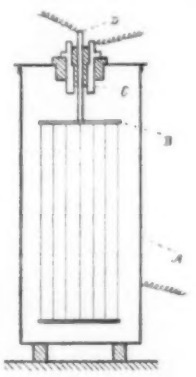


Fig. 2

generally equal to and sometimes greater than those of the morning.

The following numbers which represent the observations made upon one day are typical and show this variation:

Exposure.	Excited radioactivity.
9 A. M.—11 A. M.	.8
1 P. M.—3 P. M.	.6
6 P. M.—8 P. M.	1.0
9 P. M.—11 P. M.	1.1

The observations were made in Toronto between September 5 and 12, and between the 19th and 23d, those made at Niagara occupying the interval. The values in the two series at Toronto exhibited similar variations and were confined in both cases within the limits mentioned. The weather throughout, except for a few showers, was uniformly fine.

In conducting the experiments at Niagara Falls the electrometer and its attachments were set up in the basement of the landing-station at the foot of the inclined railway. It was a large room having stone walls and a cement floor, and, being fairly dry, was well suited for making the tests. The electrical machine which was intended for charging the wire was also located in this room, and the wire to be exposed was led from it out of a window and suspended in three stretches of about 30 meters each, the insulation being secured as already described. The situation was admirably adapted for making exposures, as the wire could be led within a meter or two of the vast mass of falling water. The first length of wire was generally enveloped in a very fine spray, that which surrounded the second was heavier, while the down-pour upon the third resembled the heaviest rain. A point of peculiar interest in connection with the first exposure was that the wire upon suspension in the spray immediately became negatively charged to a potential of about 7,500 volts. This voltage was maintained with but little variation, both day and night, during the period covered by the experiments and the sign of the electrification was invariably negative.

The results of a number of tests with the different sections of the wire showed that the removal of the third generally caused a drop in the potential of the remaining sections from 7,500 volts to about 5,500 volts, while the first section, when exposed alone, gave a potential varying from 3,000 to 4,000 volts. From this it was evident that the spray was a cause of the electrification and that the potential of the wire was largely determined by its density. On account of the permanency of this electrification of the exposed wire, the electrical machine necessary in the Toronto experiments was not employed.

In testing for induced radioactivity, the wire was exposed for periods of about two hours and was removed in sections, each section being replaced by a new length. The same method of testing was used as in Toronto and the results expressed in terms of the standard radioactive substance. Exposures were made on four different days with the following results, *A*, *B*, and *C* denoting the sections of the wire, of which *A* was that nearest the observing station and *C* that nearest the waterfall.

Date.	Section of wire tested.	Induced radioactivity. Saturation current of standard substance=1.
Sept. 12	*A*	0.1
	B	0.31
	C	None observed.
Sept. 13	*A*	0.16
	B	None observed.
	C	Not exposed.
Sept. 16	*A*	0.13
	B	0.14
	C	0.11
Sept. 17	*A*	0.15
	B	0.12
	C	None observed.

From these numbers it will be seen that but little variation was observed in the radioactivity excited in the sections *A* and *B*. In *C*, however, which was nearest the waterfall, measurable radioactivity was present in only one of three exposures. Ordinarily this section was drenched by masses of falling water in addition to being surrounded by fine spray such as enveloped the rest of the wire. But on September 16 the air currents during exposure were such as to drive aside the sheets of water and permit only the fine spray to come in contact with the section. As already stated, the spray enveloping the section *B* was generally heavier than that in contact with *A*, but the condition was not permanent, as the spray was blown about by gusts of wind whose direction was continually changing in the gorge.

The chief interest attaching to the results was that the radioactivity excited was much less than that in Toronto. It will be noticed that the greatest amount of radioactivity observed at Niagara Falls was 0.3 while the least observed in Toronto during the period covered by the experiments was 0.6. The numbers also show that on the average the radioactivity excited at Toronto was at least from five to six times greater than that induced at the Falls. The observations were not made in the two places at the same time and a direct comparison is therefore impossible, but as there was no break in the weather during the progress of the experiments and as the values found in Toronto before going to the Falls were almost the same as those obtained on returning, one is warranted in concluding that the air at the foot of the waterfall permanently possesses less power to excite radioactivity than the air of localities at some distance. While the experiments were in progress the spray was frequently examined for radioactivity. This was done by collecting a quantity, evaporating it and testing the containing vessel. In no case was any trace of radioactivity observed.

Assuming then that excited radioactivity is caused by the presence in the atmosphere of some peculiar constituent, the experiments which have been described would seem to show that this constituent is present to a much less degree in the atmosphere in the neighborhood of waterfalls than in places remote from them. That it is possible to reduce the amount of this constituent present in the atmosphere is shown by some experiments recently performed in the physical laboratory of the University of Toronto. The windows and doors of a large room which had been well aired were closed and, while of course they were not made air-tight, it may be assumed, as they were close fitting, that the quantity of outside air which they admitted was relatively small. An electrical machine at one end of the room was set in action and a number of zinc disks attached to a wire leading from its negative terminal were suspended for an hour simultaneously at different points in the room. Upon testing these disks for radioactivity by the method employed by C. T. R. Wilson,* it was found that the radioactivity excited in the disks regularly increased with the distance from the machine.

It was also found, when a series of disks were consecutively exposed for an hour in a fixed position in the room after it had been well aired and closed, that the radioactivity excited regularly diminished with the time. The admission of a considerable volume of fresh air, as by the opening of a window, immediately caused an increase in the amount of radioactivity excited in the exposed disks. It was evident, therefore, that the electrical machine in action served as a means of removing from the atmosphere surrounding it the constituent upon whose presence the excited radioactivity depended.

In seeking for an explanation of the diminished radioactivity excited at the Falls, the experiments just described suggest the presence of an agency having an effect similar to that of the electrical machine on the

* Read before the American Physical Society, at Washington, December 31, 1902.

† Wied. Ann., Bd. 46, p. 584 (1892).

‡ J. J. Thomson, Discharge of Electricity Through Gases, p. 17.

§ Wied. Ann., Bd. 47, p. 406 (1892).

‖ Phys. Zeit., No. 40, p. 590 (1901).

¶ Phil. Mag., No. 49, pp. 1 and 161 (1900).

* Proc. Roy. Soc., vol. 68, p. 151 (1901).

air in the room. The negative electrification of the wire when in the spray area pointed to the presence of this agency in the spray itself. The time at the writer's disposal did not permit of a direct investigation into the charge carried by the spray, but the negative electrification of the wire, which it will be remembered was always present, would seem to indicate a similar electrification of the spray.

That this was the case may be deduced from the results of some recent experiments by Schmauss,* who found that water became negatively electrified when dropped through air traversed by Röntgen rays. He explained his results by a reference to the experiments of Rutherford,† and of Zeleny,‡ in which it was shown that a stream of air, when ionized by Röntgen rays and directed against an insulated conductor, imparted to it a negative charge owing to the greater velocity of diffusion of the negative ions. These experiments, in which the gas was in motion and the insulated conductor at rest, Schmauss considered the converse of his own.

Now in the experiments we are considering we have spray moving through air which from Lenard's observations contained a considerable excess of negative ions. The moving spray, according to Schmauss's results, would acquire a negative charge from the air present and would then be in a condition to attract to itself the radioactive emanation and on falling would carry it down to the river below. This process would result in a diminution in the amount of the emanation present in the air at the foot of the waterfall and would therefore account for the small amount of induced radioactivity observed in that locality. This explanation requires the spray itself to be radioactive, but when the enormous volume of the spray and the very limited amount of induced radioactivity observed in the locality are taken into account, together with the known decay of induced radioactivity, it would appear reasonable to conclude that experiments conducted with very much larger quantities of spray than those in the writer's tests would be necessary to obtain observable results.

The foregoing would also serve to explain the negative electrification of the suspended wire. From the observations of Lenard we should expect a positive charge to be developed on the wire by the splashing of the spray. Schmauss has shown, however, that the negative charge gained by drops of water in falling through ionized air may be so great as to overcome the Lenard effect, and since the air enveloping the spray at the fall was not only ionized but also contained an excess of negative ions it is evident that all the conditions were present for producing a negative electrification of the suspended wire. It is probable, too, that a considerable portion of the negative charge developed on the wire was taken up directly from the negatively charged air which was constantly in motion about it.

IV. *Radioactive Rain and Snow.*—In order to ascertain, if possible, the effect of variations in the weather upon the radioactive state of the atmosphere, the writer made a series of daily observations in the month of November. During this period both rain and snow storms occurred. The falling of rain was not found to produce any marked change in the radioactive power of the atmosphere, although, as already shown by C. T. R. Wilson,§ the rain itself when tested was active. The falling of snow, however, was accompanied by a very considerable drop in the value of the excited radioactivity. For example, on November 25 the air was dry and cold and the morning exposure gave a value of 0.92, that for the afternoon exposure being 0.66. The next morning snow began to fall heavily and an exposure was made in it for two hours. The resulting value for the excited radioactivity was 0.3. The snowfall continued throughout the day and the value for the afternoon exposure was again 0.3. This storm was general throughout Ontario and the snow, which fell to a depth of about three inches, remained for some days on the ground and did not entirely disappear until November 30. Tests made for excited radioactivity in the interval showed values ranging from 0.2 to 0.4. On December 1 an exposure made about noon gave a value of 0.9. On this day the weather was again mild and the snow had disappeared. Exposures made in the mornings of December 2, 3, 4, and 5 gave the values, 0.8, 1.1, 0.9, 0.9, respectively. The weather continued mild until December 5, when the temperature dropped below 0 deg. C. On December 6 the cold weather still prevailed and an exposure made from 1 to 3 o'clock in the afternoon gave a value of 0.92. Shortly after 3 o'clock a light fall of fine snow began, which continued throughout the night. An exposure was made from 3:30 to 5:30 P. M. and also one from 9 to 11 P. M. The resulting value for the former was 0.2 and for the latter 0.32. As the numbers just given indicate, the falling of snow on both occasions was accompanied by an immediate drop in the excited radioactivity. It will also be noticed that while the ground was covered with snow from the first fall the diminished activity continued. The snow on both occasions was collected as it fell, melted and evaporated, and the residue found to be highly radioactive. Snow which fell in the first storm was tested after it had lain two days on the ground and was found still to possess about one per cent of its original activity.

These results, it will be seen, lend support to the theory that the constituent of the atmosphere to which the excitation of radioactivity is due is an emanation from the earth's surface. It would also seem from the values found for the induced radioactivity that this emanation is cut off to a considerable extent when a wide area of the earth's surface is thickly covered with snow.

The limited number of observations made hardly justifies a definite conclusion as to the manner in which rain and snow become radioactive; but it is possible that water vapor in moving through the air, whether in the form of clouds or otherwise, gains a negative charge, in the same manner as the spray at Niagara Falls attracts to itself the emanation in the air, and consequently becomes radioactive. This view is supported by the results of some experiments recently made by the writer. Water vapor was condensed from the atmosphere upon the surface of a number of cylinders containing a freezing mixture of ice and salt. The water thus obtained was evaporated in a metallic tray and the residue tested for radioactivity. Such tests were made daily for a period of two weeks. In most of them no radioactivity was observed, but slight traces were noticeable in several, and on four occasions the radioactivity excited was very marked. The experiments were all conducted with equal care and no cause was apparent for the different results of the observations.

The thanks of the writer are due to Mr. J. S. Plaskett, B.A., for assistance in conducting the experiments which at Niagara were attended with considerable difficulty, and to Mr. J. C. Rothery, superintendent of the Niagara Falls Park and River Railway for facilities afforded in transporting the apparatus.

* Wied. Ann, Bd. 9, pp. 284-237 (1902).
† Phil. Mag., vol. 43, p. 241 (1897).
‡ Ibid., vol. 46, p. 120 (1898).
§ Proc. Camb. Phil. Soc., vol. xi., pt. vi., p. 428.

MAGNETIC ALLOYS.

By V. QUITTNER.

MAGNETISM and electricity are two nearly related forces of nature. Their first known and most obvious effects are quite similar; the magnet attracts iron, and the electrified body attracts other bodies. These properties were known in ancient times, and their similarity frequently caused confusion. Afterward it was learned that the similarity is still greater. Like magnetic poles repel each other, and so do bodies similarly electrified; unlike magnetic poles attract each other, and so do oppositely electrified bodies. The law of attraction and repulsion is also the same for both forces —the attraction or repulsion is inversely proportional to the square of the distance.

Yet there is one fundamental difference between magnetism and electricity, a difference long recognized and still pointed out to the student as the first means of discrimination. All bodies, without exception, may be electrified, but magnetic properties are confined to a few substances. It was believed at first that the only substances capable of magnetization were the various metallic forms of iron and a few of its other compounds, such as magnetic pyrites and the lodestone, or magnetic iron ore, in which the Greeks first discovered magnetism. Later two other metals, cobalt and nickel, were found to possess magnetic properties in a high degree. Iron, cobalt, and nickel are the only metals whose magnetic character is easily recognizable. Nickel coins are attracted almost as strongly as bits of iron by an ordinary magnet.

By the aid of very powerful electro-magnets, however, magnetic phenomena have been detected in connection with other metals. Manganese, chromium, platinum, palladium, osmium, and a few other metals have been shown to be very slightly magnetic, in the same way as iron, nickel, and cobalt; that is to say, they are attracted by either pole of a magnet. Nearly all other metals exhibit the peculiar phenomenon of diamagnetism; that is, they are repelled by both the north and the south pole of a magnet. Bismuth is the most strongly diamagnetic. Among other diamagnetic metals are antimony, zinc, tin, lead, silver, gold, mercury, copper, and tungsten. But both the magnetism of one group and the diamagnetism of the other are extremely feeble in comparison with the magnetic power of iron, cobalt, and nickel. For example, the diamagnetism of bismuth, which far surpasses that of all other substances, is 2,500,000 times weaker than the magnetism of iron. Practically, therefore, we are still restricted to the three well-known magnetic metals.

No satisfactory explanation has yet been given of the fact that these three metals are so strongly magnetic. Chemically, they are nearly related and form, with chromium and manganese (which are also slightly magnetic) the "iron group" of elements. In striking contrast to the members of other groups of metals, these three have nearly equal atomic weights (iron 56.0, nickel 58.7, cobalt 59.0). This approximate coincidence of atomic weight may have some connection with the similarity of magnetic properties, but at present we have no positive knowledge of such connection.

It is usually assumed that magnetism is a special property of the atoms of these metals. Each atom is roughly pictured as surrounded by an electric current, like a little electro-magnet. Now, if all these magnetic atoms are so turned, by an external magnetic field, that all the north poles point in one direction and all the south poles in the opposite direction, the entire piece of metal acts like one large magnet of a strength equal to the sum of the strengths of the separate atomic magnets. If the elementary magnets are not so arranged they neutralize each other's effects, so that the metal, as a whole, is unmagnetic, though each atom is still a magnet. In the present age of the ionic theory, the theory of magnetism is often modified by substituting for the circular current in the atom itself, an electron or particle of negative electricity, revolving with great velocity around the positively-charged atom (or ion), like a planet around the sun. It is not difficult to conceive that negative electricity, thus moving rapidly around the atom, would have at exterior points precisely the same effect as a current flowing around the atom, for the current and the revolving electron are essentially identical, each being simply electricity in motion. On this theory every atom of iron is regarded as a little solar system, in which the sun is represented by a positive ion and the planet or planets by one or more negative ions revolving about it and held in their orbits by its attraction. In both cases the motion, once acquired, would continue for ever, for neither in interstellar nor in interatomic space is there anything of the nature of atmospheric resistance which could retard and ultimately destroy the motion.

This theory of magnetism, of which the fundamental principles were enunciated by Ampère long ago, gives a very good explanation of the magnetic properties of iron, but it does not explain why such properties are possessed, in a high degree, only by the three metals, iron, cobalt, and nickel. We may imagine that the atoms of these metals alone have the solar system structure, or that in other elements the motion of the electron around the atom is very slow, but this does not explain the "preferred position" of these three metals. We are compelled to assume that the atoms of iron, cobalt, and nickel are distinguished *ab initio* by these magnetic properties—that magnetism is, so to speak, a privilege conferred on them alone, and belonging to them as truly as their weights and their chemical properties.*

But this conception of magnetism inherent in atoms from the beginning must now, perhaps, be abandoned, for Dr. Hensler has succeeded in making highly magnetic alloys of entirely unmagnetic, and even of diamagnetic, metals. Such alloys may be composed of a great variety of metals. Hensler mentions copper, manganese, aluminium, tin, arsenic, antimony, bismuth, and lead. With the exception of manganese, which is very slightly magnetic, all of these metals are diamagnetic.

The alloys which could be magnetized most strongly were composed of copper, manganese, and aluminium, the quantities of manganese and aluminium being proportional to their atomic weights (55.0 to 27.1 or about 2 to 1). The maximum magnetization increases rapidly with increase of manganese, but alloys containing much manganese are exceedingly brittle and can not be wrought. The highest practicable proportion of manganese at present is 24 per cent.

These magnetic alloys were studied last year by Hensler, Haupt, and Starck, and Gumlich has recently examined them at the Physikalisch-technischen Reichsanstalt, with very remarkable and interesting results.

The two alloys examined were composed as follows:

Alloy I.—Copper 61.5 per cent, manganese 23.5 per cent, aluminium 15 per cent, lead 0.1 per cent, with traces of iron and silicon.

Alloy II.—Copper 67.7 per cent, manganese 20.5 per cent, aluminium 10.7 per cent, lead 1.2 per cent, with traces of iron† and silicon.

Alloy II. could be worked without difficulty, but alloy I. was so brittle that it broke under the hammer. A bar 7 inches long and ¼ inch thick was obtained by grinding. This broke in two during the measurements but, fortunately, without invalidating them. Such a material is evidently unsuited to practical uses.

In magnetic strength, however, alloy I. proved far superior to alloy II., which contained smaller proportions of manganese and aluminium. Alloy I. showed magnetic strengths up to 4.5 kilogauss, while the highest magnetization obtained with alloy II. was only 1.9 kilogauss.‡ But even alloy II. may be called strongly magnetic, for its maximum magnetization is about one-tenth that of good wrought-iron (18 to 20 kilogauss), or one-sixth that of cast iron (10 to 12 kilogauss). Alloy I. is nearly equal in magnetic properties to nickel, which can be magnetized up to about 5 kilogauss.

The behavior of the magnetic alloys at high temperatures is very peculiar. Alloy I. is indifferent to temperature, changes in which scarcely affect its magnetic properties, but the behavior of alloy II. is very different. Prolonged heating to 110 deg. C. produces a great increase in its capability of magnetization, which, after 544 hours' heating, rises from 1.9 to 3.2 kilogauss, approaching the strength of alloy I. But when alloy II. is heated to 165 deg. C., its capability of magnetization falls again and the material suffers permanent injury, which can be partly, but not wholly, cured by prolonged heating.

Another singular phenomenon was exhibited by both of these alloys. When a bar of iron is magnetized by an electric current, it acquires its full magnetic strength almost instantaneously on the closure of the circuit. The magnetic alloys, on the contrary, do not attain their full magnetization for several minutes. In some of the experiments a gradual increase was observed even after the current had been flowing five minutes.

I desire also to call attention to another remarkable fact which, though it may be the result of pure chance and have no significance, is too striking to be disregarded. I have already mentioned that the three mag-

* This assumption is not contradicted by the fact that the compounds of iron, cobalt, and nickel are very slightly or not at all magnetic, for these compounds contain, not the complete atoms, but only the ions of the metals. The magnetic properties predicated of the atoms are not necessarily possessed by the ions, for it is evident from the explanation given above that the atom must lose its magnetism when it loses its electrons.

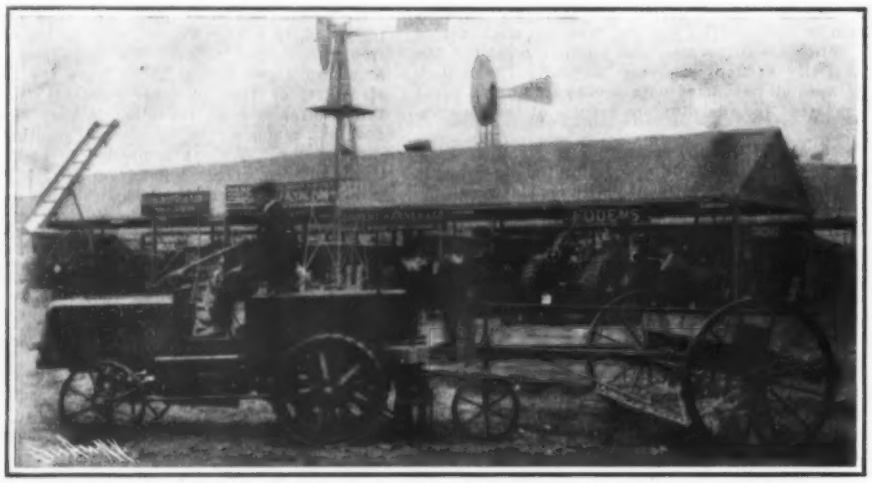
† The percentage of iron is too small to account for a thousandth part of the magnetic strength of the alloys.

‡ A gauss, or C.G.S. unit, is the unit of magnetic induction, or strength of magnetic field; 1,000 such units make a kilogauss. The maximum values of the magnetic induction were obtained with a magnetizing force H = 150 C.G.S. units.

netic metals have almost equal atomic weights, namely, iron 56.0, cobalt 59.0, nickel 58.7. Now, if the "mean atomic weights" of these magnetic alloys are calculated from the atomic weights and proportions of their constituents, according to the ordinary rule for mixtures, the following surprising results are obtained:

ALLOY I.

	Atomic weight.	Percentage.	
Copper	63.6	61.5	$63.6 \times 0.615 = 39.12$
Manganese	55.0	23.5	$55.0 \times 0.235 = 12.93$
Aluminium	27.1	15.0	$27.1 \times 0.15 = 4.07$
Lead	206.9	0.1	$206.9 \times 0.001 = 0.21$
"Mean atomic weight"			56.33



SCOTT GASOLINE ROTARY CULTIVATOR WITH SEED-DRILL ATTACHED.

ALLOY II.

	Percentage.	
Copper	67.7	$63.6 \times 0.677 = 43.08$
Manganese	20.5	$55.0 \times 0.205 = 10.28$
Aluminium	10.7	$27.1 \times 0.107 = 2.90$
Lead	1.2	$206.9 \times 0.012 = 2.48$
"Mean atomic weight"		58.74

These "mean atomic weights" of the magnetic alloys are approximately equal to the atomic weights of the three magnetic metals. The coincidence is the more striking as no other known alloy has a "mean atomic weight" of this approximate value. It would be hazardous, however, to base any theory upon this singular fact.

Hensler's alloys are not likely to find any practical application, for their maximum magnetic strength under the most favorable conditions is barely one-fourth that of wrought iron or steel. But the mere existence of such alloys justifies the hope that others may be produced which will even surpass iron in magnetic properties. Such an alloy, if not too brittle or too soft, would certainly find extensive employment in the construction of electrical machinery and apparatus. Even if this hope should not be fulfilled, the discovery of the magnetic alloys is of great theoretical importance, for it not only enlarges our knowledge and conceptions of magnetism but also promises an insight into the very obscure subject of alloys and metallic solutions.—Translated from Prometheus.

AN INTERESTING 40-TON BLOCK-SETTING CRANE FOR HARBOR CONSTRUCTION.

By the English Correspondent of SCIENTIFIC AMERICAN.

THERE has recently been completed in Great Britain for the construction of the harbor at Table Bay in South Africa a 40-ton block-setting titan which possesses several interesting features, the most important being the unusual working radius of 115 feet. Owing to the peculiarities of the constructional work and engineering difficulties in connection with this contract, the engineers, Messrs. Coode, Son & Matthews, Westminster, London, who are carrying out the undertaking, found that a special type of titan, having a large radius and several other important points, was requisite for the successful completion of the work.

The accompanying illustration shows this titan after construction undergoing its official trials in the yard of the builders, Messrs. Cowans, Sheldon & Co., at Carlisle. The titan is carried upon thirty-two wheels, sixteen on either side. The wheels are 2 feet 6 inches in diameter, of cast-iron centers and shod with shrunk-on steel tires, carried upon axles 6¾ inches in diameter. The titan travels upon two sets of rails having a gage of 3 feet 6 inches and 31-foot centers. Each wheel is fitted with four volute springs, making 128 springs for the whole machine.

Steel plates and angles of box section constitute the material throughout for the main uprights of the carriage and the diagonal cross girders. A circular box girder built up of steel plates and angles to which is fixed the revolving rack of cast iron is carried on top of the main cross girders. This girder also carries a pathway of wrought steel 32 feet in diameter, there being a similar pathway fixed to the underside of an upper circular girder which carries the cantilevers. Between these pathways there is a live roller ring of cast-steel rollers. The cantilevers weigh 135 tons and are 175 feet in length with a depth of 11 feet. The monkey runs on steel bridge rails bolted on top of the cantilevers, which are built of steel plates and angles of lattice type, and wind bracings of steel plates, angles, and channels are fixed outside each cantilever. The ballast box for containing the requisite quantity of ballast is carried under the tail end of the cantilevers, where is placed the machinery.

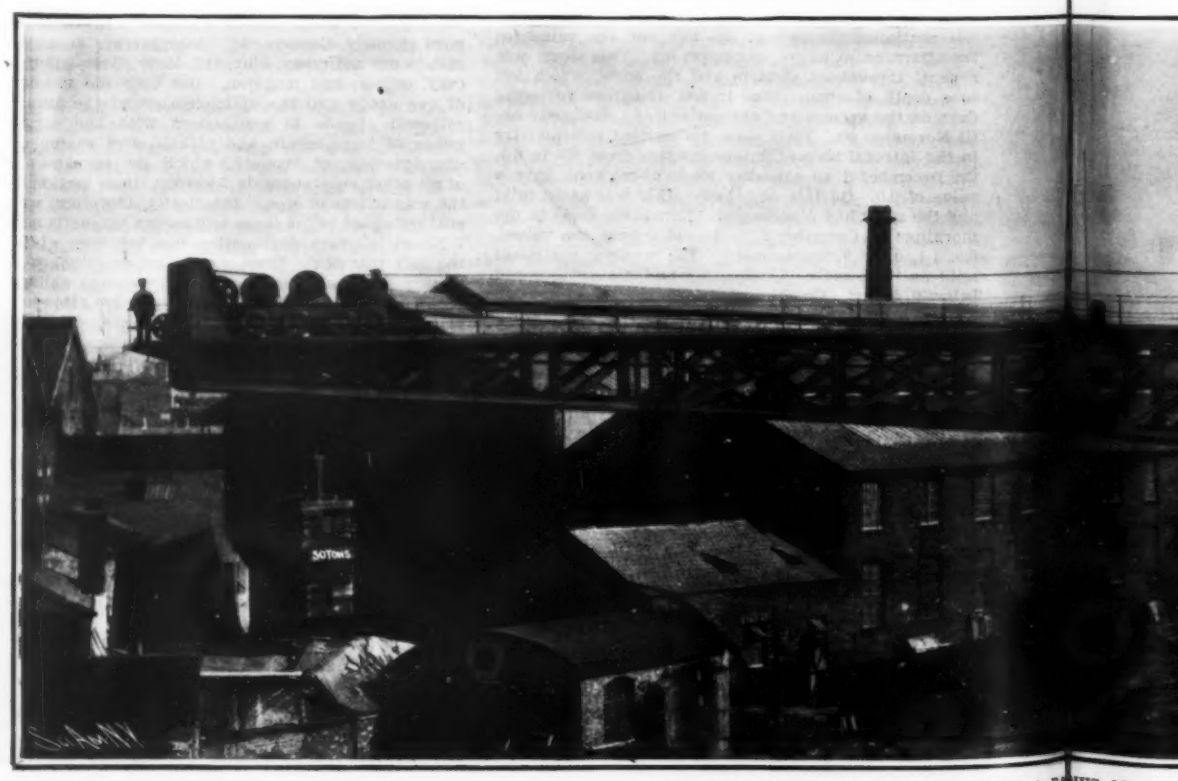
One pair of engines serves to work the whole of the motions by the agency of friction and claw clutches. The engine cylinders have a bore of 12 inches and a stroke of 18 inches, and work at a steam pressure of 80 pounds per square inch. A vertical type boiler 12 feet in height by 6 feet diameter fitted with cross tubes generates the steam. A strap brake of the general pattern controls the main lifting purchase, which is also replete with a Matthews patent hydraulic brake, which insures perfect control over the load. The operator is afforded a clear, uninterrupted view of the operations, and the whole of the controlling levers over the various movements of the machine are brought together at the front of his cabin within convenient reach so that he has complete and instant control over the whole machine. The movements of the titan comprise lifting and lowering of the load, backing crab in and out, revolving, and traveling. With a full load of 40 tons the specified lifting speed is 8 feet per minute, though under test with a load of 50 tons—an excess of 10 tons over the contract load—a speed of 16 feet per minute was obtained, which was double the speed contracted for.

The titan is also provided with a separate crab for grabbing operations. The cheeks of the crab are made of steel plates, stiffened with angles riveted round the edge and with cast-iron bosses fitted with brass bushes for carrying the shafts for the various motions. The cast-iron barrel is 5 feet 2½ inches long with a diameter of 6 feet 10 inches and is capable of taking the whole of the rope without overlapping. The lifting rope is 134 feet long and 4 inches in circumference. There are four racking ropes each of 3½ inches circumference. Two are 237 feet long and the remaining pair 121 feet long. The grabbing rope is 260 feet long by 4½ inches circumference. The height to the rail on which the traveling monkey runs is 36 feet 3 inches, and the over-all height of the crane is 51 feet. The traveling monkey covers a range of action from 20 feet minimum to 115 feet maximum radius.

For the purposes of testing the appliance a test load of 50 tons was used representing an excess of 10 tons over the contracted load, and in all the various trials of the different motions the specified requirements were largely exceeded, thereby leaving ample margin of power.

In the lifting tests with a load of 50 tons the actual speed obtained was 16 feet, whereas the specified speed was 8 feet per minute, while with a load of 10 tons the actual speed was 70 feet as compared with 50 feet per minute. The traveling speed of the titan with a full load was 50 feet per minute, the racking speed of the traveling monkey with full load suspended was 144 feet per minute against a contracted speed of 20 feet per minute, while the racking of the traveling monkey without the load was 144 feet per minute against the specified speed of 50 feet per minute. In the slewing motion a complete revolution with full load was accomplished in 1 minute 37 seconds, giving a speed of 446 feet per minute at the hook, whereas the contract was for a complete revolution in 3 minutes or a speed of 240 feet per minute at the hook.

The titan is at present being erected at Tynemouth for the construction of a pier, as operations are not yet advanced sufficiently for its employment at Table Bay.



A FORTY-TON STEAM CRANE WITH A RADIUS OF ONE

THE SCOTT GASOLINE-MOTOR-PROPELLED AGRICULTURAL TRACTOR.

By the English Correspondent of SCIENTIFIC AMERICAN.

AT the recent show of the British Royal Agricultural Society great interest was centered in the Scott motor tractor and its various ingenious attachments for farming purposes. These different appliances are the inventions of Prof. John Scott, of Edinburgh, Scotland, who is a well-known authority on agricultural topics both in Great Britain and this country. He was the first to realize the possibilities of applying motor traction to agricultural implements, and exhibited the first motor cultivator in 1899. During the intervening years he has effected several important improvements and patented many applications of the internal-combustion motor to this class of work.

The Scott gasoline-propelled motor tractor, as will be seen from the accompanying illustration, is a small and compact machine. The chassis is carried upon three wheels, the two forward wheels serving for steering purposes, while the drive is transmitted to one centrally-placed rear wheel of wide tread, so as to obtain a complete purchase upon the ground over which it is traveling. The front wheels are of chilled cast iron, 2 feet 2 inches diameter, with the axles mounted on vertical spindles, each of which is provided with a spiral spring interposed for the purpose of absorbing all road shocks. The rear wheel is 3 feet diameter, with a 17-inch tread. It is built of steel plate, and strengthened with diagonally-placed grips which are riveted to the axle and rim of the wheel. It runs solid with the axle, as there is no differential gear, and the single sprocket for the chain which transmits the speed from the gear box is keyed to the axle outside the frame. The axle is carried upon horn brackets with a pair of stout spiral compression springs interposed with the sliding blocks or bearings.

The motor in this tractor is a 24-horse-power, four-cylinder, standard Aster engine, fitted with mechan-

ically-operated inlet valves, and having all the latest features. The engine power is transmitted through a leather cone clutch of heavy design and large diameter. Attached to a short clutch shaft is a bevel pinion. This is driven alternately as desired by one or the other of a pair of large bevel gears, which are fitted on either side and provide either the forward or reverse motion to the tractor. These two bevel gears are mounted on a first-motion or primary shaft, which also carries a pair of spur change-speed gears. These mesh with a corresponding pair of spur gears on a lower countershaft, at the outer end of which is fixed the single sprocket which transmits the engine power through a heavy Brampton chain to the corresponding sprocket attached to the axle of the rear driving wheel.

At the outer end of the primary shaft is a pulley, which renders the motor suitable for driving machinery by a belt when the tractor is stationary. As the pulley is mounted on the primary shaft, it can be run quite independently of the change-speed gearing, the drive being through one of the two large bevel gears, according to which direction it is desired to rotate the pulley.

The tractor has speeds ranging from three to seven miles per hour both forward and reverse. There are two change-speed levers working in quadrants, placed convenient to the driver's seat. One lever actuates the meshing of the bevel wheels, while the other operates in connection with the particular speed required. The engine and transmission are carried upon a channel steel frame substantially stiffened with cross members to insure rigidity. Behind the driver's seat are carried the two water tanks coupled together, with a combined capacity of 40 gallons. The gasoline reservoir is also carried here, being placed transversely to the water tanks, and it carries 10 gallons of fuel. Rack and pinion wheel steering is used. An ingenious arrangement is also provided by means of which the driver, when plowing, can raise or lower the right-hand side wheel, thereby rendering it a furrow wheel, and consequently maintaining the equilibrium of the tractor. The raising or lowering of this wheel is effected by a lever and suspending quadrant worked by the driver.

The drawbar is fitted with an arrangement for raising or lowering it to suit the height of the draft connections of various implements. Also, in one type of Scott tractor, this raising and lowering arrangement can be made use of for the motorman to regulate the depth of the furrow, and thereby dispense with the attendant to the plow.

In one of the motor tractor and cultivator types the former comprises a four-wheeled vehicle. In this system the front steering wheels are of light though strong construction, while the rear driving wheels are of heavy construction, similar in design to the single wheel on the three-wheeled tractor, only with a narrower tread. The mechanism, however, is practically the same, the horse-power of the engines ranging from 20 to 30 horse-power according to the requirements of the work it is desired to carry out. By a slight interchange of parts the same tractor can be made to carry out a variety of operations, such as cultivation, seed planting, reaping, threshing, etc., besides numerous stationary functions such as grinding, chaff cutting, churning, pumping, sawing wood, or running a dynamo. It also serves as a tractor for haulage upon the roadways. A comprehensive idea of the work that can be carried out with this type of machine as compared with either horse or stationary steam motive power is shown in the following results recently obtained:

MOTOR CULTIVATION.

Area of land cultivated in one day, 6 acres.	
Gasoline and lubricating oil.....	$2.82
One man's wages.....	1.25
Interest, wear and tear, and depreciation on cost of tractor $1,500.....	1.93
Total cost of working 6 acres.....	$6.00
Total cost of complete cultivation per acre	$1.00

SCOTT AGRICULTURAL MOTOR TRACTOR AND PLOWING ENGINE.

HORSE CULTIVATION.

One day's work, 1 acre.	
Two horses per day.....	$1.63
One man's wages.....	.87
Cost of plowing only one acre.....	$2.50

The advantage, as will be seen, is conclusively in favor of the motor tractor, which will accomplish the same amount of work as the animal system—sixty per cent cheaper. The Scott tractor is being extensively adopted for agricultural purposes in the British Isles, which result is due to its simplicity of construction and operation, low cost of working, and utilitarianism.

CONCEPTIONS OF MAGNETISM.

MAGNETISM, definitely founded by Gilbert (1600) and put on a quantitative basis by Coulomb (1785), was first made the subject of recondite theoretical treatment by Poisson (1824-27). The interpretation thus given to the mechanism of two conditionally separable magnetic fluids facilitated discussion and was very generally used in argument, as for instance by Gauss (1833) and others, although Ampère had suggested the permanent molecular current as early as 1820. Weber (1852) introduced the revoluble molecular magnet, a theory which Ewing (1890) afterward generalized in a way to include magnetic hysteresis. The phenomenon itself was independently discovered by Warburg (1881) and by Ewing (1882) and has since become of special practical importance.

Faraday in 1852 introduced his invaluable conception of lines of magnetic force, a geometric embodiment of Gauss's (1813, 1839) theorem of force flux, and Maxwell (1855, 1862, et seq.) thereafter gave the rigorous scientific meaning to this conception, which pervades the whole of contemporaneous electromagnetics.

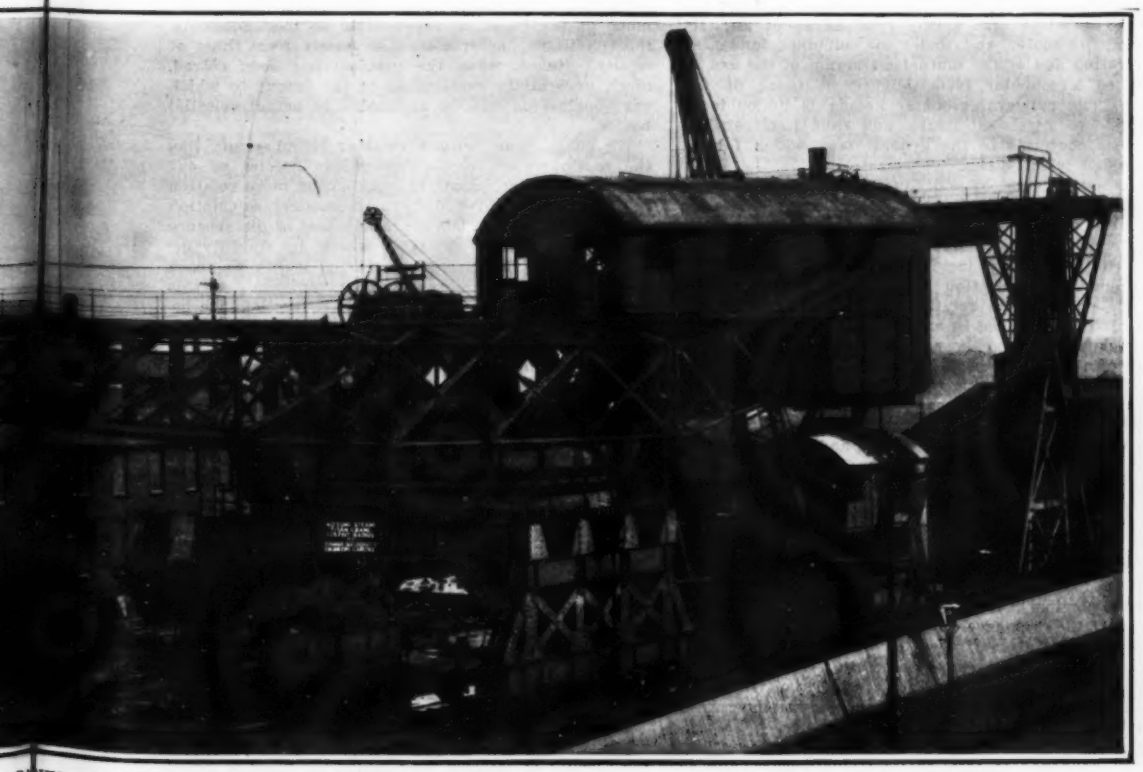
The phenomenon of magnetic induction, treated hypothetically by Poisson (1824-27) and even by Barlow (1820), has since been attacked by many great thinkers, like F. Neumann (1848), Kirchhoff (1854); but the predominating and most highly elaborated theory is due to Kelvin (1849, et seq.). This theory is broad enough to be applicable to æolotropic media and to it the greater part of the notation in current use throughout the world is due. A new method of attack of great promise has, however, been introduced by Duhem (1888, 1895, et seq.) in his application of the thermodynamic potential to magnetic phenomena.

Magneticians have succeeded in expressing the magnetic distribution induced in certain simple geometrical figures like the sphere, the spherical shell, the ellipsoid, the infinite cylinder, the ring. Green in 1828 gave an original but untrustworthy treatment for the finite cylinder. Lamellar and solenoidal distributions are defined by Kelvin (1850), to whom the similarity theorems (1856) are also due. Kirchhoff's results for the ring were practically utilized in the absolute measurements of Stoletow (1872) and of Rowland (1878).

Diamagnetism, though known since Brugmans (1778), first challenged the permanent interest of science in the researches of Becquerel (1827) and of Faraday (1845). It is naturally included harmoniously in Kelvin's great theory (1847, et seq.). Independent explanations of diamagnetism, however, have by no means abandoned the field; one may instance Weber's (1852) ingenious generalization of Ampère's molecular currents (1820) and the broad critical deductions of Duhem (1889) from the thermodynamic potential. For the treatment of æolotropic magnetic media, Kelvin's (1850, 1851) theory seems to be peculiarly applicable. Weber's theory would seem to lend itself well to electronic treatment.

The extremely complicated subject of magnetostriction, originally observed by Matteuci (1847) and by Joule (1849) in different cases, and elaborately studied by Wiedemann (1858, et seq.), has been repeatedly attacked by theoretical physicists, among whom Helmholtz (1881), Kirchhoff (1885), Boltzmann (1879), and Duhem (1891) may be mentioned. None of the carefully elaborated theories accounts in detail for the facts observed.

The relations of magnetism to light have increased in importance since the fundamental discoveries of Faraday (1845) and of Verdet (1854), and they have been specially enriched by the magneto-optic discoveries of Kerr (1876, et seq.), of Kundt (1884, et seq.), and more recently by the Zeemann effect (1897, et seq.). Among the theories put forth for the latter, the electronic explanation of Lorentz (1898, 1899) and that of Voigt (1899) are supplementary or at least not contradictory. The treatment of the Kerr effect has been systematized by Drude (1892, 1893). The instantaneity of the rotational effect was first shown by Bichat and Blondlot (1812) and this result has since been found useful in chronography. Sheldon demonstrated the possibility of reversing the Faraday effect. Finally terrestrial magnetism was revolutionized and made accessible to absolute measurement by Gauss (1833), and his method served Weber (1840, et seq.) and his successors as a model for the definition of absolute units



A RADIUS OF ONE HUNDRED AND FIFTEEN FEET.

throughout physics. Another equally important contribution from the same great thinker (1840) is the elaborate treatment of the distribution of terrestrial magnetism, the computations of which have been twice modernized, in the last instance by Neumeyer (1880). Magnetometric methods have advanced but little since the time of Gauss (1833), and Weber's (1853) earth inductor remains a standard instrument of research. Observationally, the development of cycles of variation in the earth's constants is looked forward to with eagerness, and will probably bear on an adequate theory of terrestrial magnetism, yet to be framed. Arrhenius (1903) accentuates the importance of the solar cathode torrent in its bearing on the earth's magnetic phenomena. Electromagnetism considered either in theory or in its applications is, perhaps, the most conspicuous creation of the nineteenth century. Beginning with Oersted's great discovery of 1820, the quantitative measurements of Biot and Savart (1820) and Laplace's (1821) law followed in quick succession. Ampère (1820) without delay propounded his famous theory of magnetism. For many years the science was conveniently subserved by Ampère's swimmer (1820), though his functions have since advantageously yielded to Fleming's hand rule for moving current elements. The induction produced by ellipsoidal coils or the derivative cases is fully understood. In practice the rule for the magnetic circuit devised by the Hopkinsons (1886) is in general use. It may be regarded as a terse summary of the theories of Euler (1780), Faraday, Maxwell, and particularly Kelvin (1872), who already made explicit use of it. Nevertheless, the clear-cut practical interpretation of the present day had to be gradually worked out by Rowland (1873, 1884), Bosanquet (1883-85), Kapp (1885), and Pisati (1890).

The construction of elementary motors was taken up by Faraday (1821), Ampère (1822), Barlow (1822), and others, and they were treated rather as laboratory curiosities; for it was not until 1857 that Siemens devised his shuttle-wound armature, and the development of the motor thereafter went *pari passu* with the dynamo to be presently considered. It culminated in a new principle in 1888 when Ferraris, and somewhat later Tesla (1888) and Borel (1888), introduced polyphase transmission and the more practical realization of Arago's rotating magnetic field (1824).

Theoretical electromagnetics, after a period of quiescence, was again enriched by the discovery of the Hall effect (1879, et seq.), which at once elicited wide and vigorous discussion, and for which Rowland (1880), Lorentz (1883), Boltzmann (1886), and others put forward theories of continually increasing finish. Nernst and V. Ettingshausen (1886, 1887) afterward added the thermomagnetic effect.—From a paper by Prof. Carl Barus on "The Progress of Physics in the Nineteenth Century."

THE EVOLUTION OF A STAR.*

By PROF. G. H. DARWIN, M.A., LL.D., PH.D., F.R.S.

THE German astronomer Bode long ago propounded a simple empirical law concerning the distances at which the several planets move about the sun, and his formula embraces so large a number of cases with accuracy that we are compelled to believe that it arises in some manner from the primitive conditions of the planetary system.

The explanation of the causes which have led to this simple law as to the planetary distances presents an interesting problem, and, although it is still unsolved, we may obtain some insight into its meaning by considering what may be called a working model of ideal simplicity.

Imagine, then, a sun round which there moves in a circle a single large planet. I will call this planet Jove, because it may be taken as a representative of our largest planet, Jupiter. Suppose next that a meteoric stone or small planet is projected in any perfectly arbitrary manner in the same plane in which Jove is moving; then we ask how this third body will move. It appears that under the combined attractions of the sun and Jove the meteoric stone will in general describe an orbit of extraordinary complexity, at one time moving slowly at a great distance from both the sun and Jove, at other times rushing close past one or other of them. As it grazes past Jove or the sun it may often but just escape a catastrophe, but a time will come at length when it runs its chances too fine and comes into actual collision. The individual career of the stone is then ended by absorption, and of course by far the greater chance is that it will find its Nirvana by absorption in the sun.

Next let us suppose that instead of one wandering meteoric stone or minor planet there are hundreds of them, moving initially in all conceivable directions. Since they are all supposed to be very small, their mutual attractions will be insignificant, and they will each move almost as though they were influenced only by the sun and Jove. Most of these stones will be absorbed by the sun, and the minority will collide with Jove.

When we inquire how long the career of a stone may be, we find that it depends on the direction and speed with which it is started, and that by proper adjustment the delay of the final catastrophe may be made as long as we please. Thus by making the delay indefinitely long we reach the conception of a meteoric stone which moves so as never to come into collision with either body.

There are, therefore, certain perpetual orbits in which a meteoric stone or minor planet may move forever without collision. But when such an immortal career has been discovered for our minor planet, it still remains to discover whether the slightest possible departure from the prescribed orbit will become greater and greater and ultimately lead to a collision with the sun or Jove, or whether the body will travel so as to cross and recross the exact perpetual orbit, always remaining close to it. If the slightest departure inevitably increases as time goes on, the orbit is unstable; if, on the other hand, it only leads to a slight waviness in the path described, it is stable.

We thus arrive at another distinction; there are perpetual orbits, but some, and indeed most, are unstable, and these do not offer an immortal career for a meteoric stone; and there are other perpetual orbits which are stable or persistent. The unstable ones are those which succumb in the struggle for life, and the stable ones are the species adapted to their environment.

If, then, we are given a system of a sun and large planet, together with a swarm of small bodies moving in all sorts of ways, the sun and planet will grow by accretion, gradually sweeping up the dust and rubbish of the system, and there will survive a number of small planets and satellites moving in certain definite paths. The final outcome will be an orderly planetary system in which the various orbits are arranged according to some definite law.

There is hardly room for doubt that if a complete solution for our solar system were attainable, we should find that the orbits of the existing planets and satellites are numbered among the stable perpetual orbits, and should thus obtain a rigorous mechanical explanation of Bode's law concerning the planetary distances.

In the first portion of my address I described the orbits in which the corpuscles move in the atoms of matter, and drew attention to the resemblance to a planetary system. It may not, perhaps, be fanciful to imagine that some general mathematical method devised for solving a problem of cosmical evolution may find another application to miniature atomic systems, and may thus lead onward to vast developments of industrial mechanics. Science, however diverse its aims, is a whole, and men of science do well to impress on the captains of industry that they should not look askance on those branches of investigation which may seem for the moment far beyond any possibility of practical utility.

The theory which I have now explained points to the origin of the sun and planets from gradual accretions of meteoric stones, and it makes no claim to carry the story back behind the time when there was already a central condensation or sun about which there circled another condensation or planet. But more than a century ago an attempt had already been made to reconstruct the history back to a yet remoter past, and, as we shall see, this attempt was based upon quite a different supposition as to the constitution of the primitive solar system. I myself believe that the theory I have just explained, as well as that to which I am coming, contains essential elements of truth, and that the apparent discordances will some day be reconciled. The theory of which I speak is the celebrated Nebular Hypothesis, first suggested by the German philosopher Kant, and later restated independently and in better form by the French mathematician Laplace.

Laplace traced the origin of the solar system to a nebula or cloud of rarefied gas congregated round a central condensation which was ultimately to form the sun. The whole was slowly rotating about an axis through its center, and, under the combined influences of rotation and of the mutual attraction of the gas, it assumed a globular form, slightly flattened at the poles. The primeval globular nebula is undoubtedly a stable or persistent figure, and thus Laplace's hypothesis conforms to the general laws which I have attempted to lay down.

The nebula must have gradually cooled by radiation into space, and as it did so the gas must necessarily have lost some of its spring or elasticity, thus permitting a greater degree of condensation of the whole. The contraction led inevitably to two results; first, the central condensation became hotter and, secondly, the speed of its rotation became faster. The accelerated rotation led to an increase in the amount of polar flattening, and the nebula at length assumed the form of a lens, or of a disk thicker in the middle than at the edges. Assuming the existence of the primitive nebula, the hypothesis may be accepted thus far as practically certain.

From this point, however, doubt and difficulty enter into the argument. It is supposed that the nebula became so much flattened that it could not subsist as a continuous aggregation of gas, and a ring of matter detached itself from the equatorial regions. The central portions of the nebula, when relieved of the excrescence, resumed the more rounded shape formerly possessed by the whole. As the cooling continued, the central portion in its turn became excessively flattened through the influence of its increased rotation; another equatorial ring then detached itself, and the whole process was repeated as before. In this way the whole nebula was fissured into a number of rings surrounding the central condensation, whose temperature must by then have reached incandescence.

Each ring then aggregated itself round some nucleus which happened to exist in its circumference, and so formed a subordinate nebula. Passing through a series of transformations, like its parent, this nebula was finally replaced by a planet with attendant satellites.

The whole process forms a majestic picture of the history of our system. But the mechanical conditions of a rotating nebula are too complex to admit, as yet, of complete mathematical treatment; and thus, in discussing this theory, the physicist is compelled in great measure to adopt the qualitative methods of the biologist, rather than the quantitative ones which he would prefer.

Although the telescope seems to confirm the general correctness of Laplace's hypothesis, yet it is hardly too much to say that every stage in the supposed process presents to us some impossibility.

Thus, for example, the ring of Saturn seems to have suggested the theory to Laplace; but to take it as a model leads us straight to a quite fundamental difficulty. If a ring of matter ever concentrates under the influence of its mutual attraction, it can only do so round the center of gravity of the whole ring. Therefore the matter forming an approximately uniform ring, if it concentrates at all, can only fall in on the parent planet and be re-absorbed. Some external force other than the mutual attraction of the matter forming the ring, and therefore not provided by the theory, seems necessary to effect the supposed concentration. The only way of avoiding this difficulty is to suppose the ring to be ill-balanced or lop-sided; in this case, provided the want of balance is pronounced enough, concentration will take place round a point inside the ring but outside the planet.

However, this is not the time to pursue these considerations further, yet enough has been said to show that the Nebular Hypothesis cannot be considered as a connected intelligible whole, however much of truth it may contain.

In the first theory which I sketched as to the origin of the sun and planets, we supposed them to grow by the accretions of meteoric wanderers in space, and this hypothesis is apparently in fundamental disagreement with the conception of Laplace, who watches the transformations of a continuous gaseous nebula. I must not pause to consider how these seemingly discordant views may be reconciled, but will merely say that I conceive both theories contain important elements of truth.

We have seen that, in order to explain the genesis of planets according to Laplace's theory, the rings must be ill-balanced or even broken. If the ring were so far from being complete as only to cover a small segment of the whole circumference, the true features of the occurrences in the births of planets and satellites might be better represented by conceiving the detached portion of matter to have been more or less globular from the first, rather than ring-shaped. Now this idea introduces us to another group of researches whereby mathematicians have sought to explain the birth of planets and satellites.

The solution of the problem of evolution involves the search for those persistent or stable forms which biologists would call species. The species of which I am now going to speak may be grouped in a family, which comprises all those various forms which a mass of rotating liquid is capable of assuming under the conjoint influences of gravitation and rotation. If the earth were formed throughout of a liquid of the same density, it would be one of the species of this family; and indeed these researches date back to the time of Newton, who was the first to explain the figures of planets.

The ideal liquid planets we are to consider must be regarded as working models of actuality, and inasmuch as the liquid is supposed to be incompressible, the conditions depart somewhat widely from those of reality. Hence, when the problem has been solved, much uncertainty remains as to the extent to which our conclusions will be applicable to actual celestial bodies.

We begin, then, with a rotating liquid planet like the earth, which is the first stable species of our family. We next impart in imagination more rotation to this planet, and find by mathematical calculation that its power of resistance to any sort of disturbance is less than it was. In other words, its stability declines with increased rotation, and at length we reach a stage at which the stability just vanishes. At this point the shape is a transitional one, for it is the beginning of a new species with different characteristics from the first, and with a very feeble degree of stability or power of persistence. As a still further amount of rotation is imparted, the stability of the new species increases to a maximum and then declines until a new transitional shape is reached and a new species comes into existence. In this way we pass from species to species with an ever-increasing amount of rotation.

The first or planetary species has a circular equator like the earth; the second species has an oval equator, so that it is something like an egg spinning on its side on a table; in the third species we find that one of the two ends of the egg begins to swell, and that the swelling gradually becomes a well-marked protrusion or filament. Finally, the filamentous protrusion becomes bulbous at its end, and is only jointed to the main mass of liquid by a gradually thinning neck. The neck at length breaks, and we are left with two separated masses which may be called planet and satellite.

In this ideal problem the successive transmutations of species are brought about by gradual additions to the amount of rotation with which the mass of liquid is endowed. It might seem as if this continuous addi-

* Abstracted from paper read at South African meeting of the British Association for the Advancement of Science.

tion to the amount of rotation were purely arbitrary and could have no counterpart in nature. But real bodies cool and contract in cooling, and I must ask you to believe that the effects of an apparently arbitrary increase of rotation may be produced by cooling.

The figures which I succeeded in drawing, by means of rigorous calculation, of the later stages of this course of evolution, are so curious as to remind one of some such phenomenon as the protrusion of a filament of protoplasm from a mass of living matter, and I suggest that we may see in this almost life-like process the counterpart of at least one form of the birth of double stars, planets, and satellites.

My Cambridge colleague Jeans has also made an interesting contribution to the subject by attacking the far more difficult case where the rotating fluid is a compressible gas. In this case also he finds a family of types, but the conception of compressibility introduced a new set of considerations in the transitions from species to species. The problem is, however, of such difficulty that he had to rest content with results which were rather qualitative than strictly quantitative.

It cannot be doubted that the supposed Laplacean sequence of events possesses a considerable element of truth, yet these latter schemes of transformation can be followed in closer detail. It seems, then, probable that both processes furnish us with crude models of reality, and that in some cases the first and in others the second is the better representative.

The moon's mass is one-eightieth of that of the earth, whereas the mass of Titan, the largest satellite in the solar system, is 1-4600 of that of Saturn. On the ground of this great difference between the relative magnitudes of all other satellites and of the moon, it is not unreasonable to suppose that the mode of separation of the moon from the earth may also have been widely different. The theory of which I shall have next to speak claims to trace the gradual departure of the mooon from an original position not far removed from the present surface of the earth. If this view is correct, we may suppose that the detachment of the moon from the earth occurred as a single portion of matter, and not as a concentration of a Laplacean ring.

If a planet is covered with oceans of water and air, or if it is formed of plastic molten rock, tidal oscillations must be generated in its mobile parts by the attractions of its satellites and of the sun. Such movements must be subject to frictional resistance, and the planet's rotation will be slowly retarded by tidal friction in much the same way that a flywheel is gradually stopped by any external cause of friction. Since action and reaction are equal and opposite, the action of the satellites on the planet, which causes the tidal friction of which I speak, must correspond to a reaction of the planet on the motion of the satellites.

At any moment of time we may regard the system composed of the rotating planet with its attendant satellite as a stable species of motion, but the friction of the tides introduces forces which produce a continuous, although slow, transformation in the configuration. It is, then, clearly of interest to trace backward in time the changes produced by such a continuously acting cause, and to determine the initial condition from which the system of planet and satellite must have been slowly degrading. We might also look forward, and discover whither the transformation tends.

Let us consider, then, the motion of the earth and moon revolving in company round the sun, on the supposition that the friction of the tides in the earth is the only effective cause of change. We are, in fact, to discuss a working model of the system, analogous to those of which I have so often spoken before; and it must suffice to set forth the result in its main outline as referring only to the past.

If we take the "day," regarding it as a period of variable length, to mean the time occupied by a single rotation of the earth on its axis; and the "month," likewise a variable in absolute length, to mean the time occupied by the moon in a single revolution round the earth, the number of days in the month expresses the speed of the earth's rotation relatively to the speed of the moon's revolution.

Now in our retrospect both day and month are found continuously shortening; but as on the whole the month shortens much more quickly than the day, the number of days in the month also falls. We may, then, ask at once, What is the initial stage to which the gradual transformation points? I say, that on following the argument to its end the system may be traced back to a time when the day and month were identical in length, and were both only about four or five of our present hours. The identity of day and month means that the moon was always opposite to the same side of the earth; thus at the beginning the earth always presented the same face to the moon, just as the moon now always shows the same face to us. Moreover, when the month was only some four or five of our present hours in length the moon must have been only a few thousand miles from the earth's surface—a great contrast with the present distance of 240,000 miles.

It might well be argued from this conclusion alone that the moon separated from the earth more or less as a single portion of matter at a time immediately antecedent to the initial stage to which she has been traced. But there exists a yet more weighty argument favorable to this view, for it appears that the initial stage is one in which the stability of the species of motion is tottering, so that the system presents the characteristic of a transitional form, which we have seen to denote a change of type or species in a previous case.

In discussing the transformations of a liquid planet we saw the tendency of the single mass to divide into two portions, and now we seem to reach a similar crisis from the opposite end, when in retrospect we trace back the system to two masses of unequal size in close proximity with one another. The argument almost carries conviction with it, but I have necessarily been compelled to pass over various doubtful points.

Tidal friction is competent to explain the eccentricity of an orbit, because this conclusion has been applied in a manner to which I shall have occasion to return hereafter.

If, as has been argued, tidal friction has played so important a part in the history of the earth and moon, it might be expected that the like should be true of the other planets and satellites, and of the planets themselves in their relationship to the sun. But numerical examination of the several cases proves conclusively that this cannot have been the case. The relationship of the moon to the earth is in fact quite exceptional in the solar system, and we have still to rely on such theories as that of Laplace for the explanation of the main outlines of the solar system.

I have not yet mentioned the time occupied by the sequence of events sketched out in the various schemes of cosmogony, and the question of cosmical time is a thorny and controversial one.

Our ideas are absolutely blank as to the time requisite for the evolution either according to Laplace's nebular hypothesis, or the meteoritic theory. All we can assert is that they demand enormous intervals of time as estimated in years.

The theory of tidal friction stands alone among these evolutionary speculations in that we can establish an exact but merely relative time scale for every stage of the process. Although it is true that the value in years of the unit of time remains unknown, yet it is possible to determine a period in years which must be shorter than that in which the whole history is comprised. If at every moment since the birth of the moon tidal friction had always been at work in such a way as to produce the greatest possible effect, then we should find that sixty million years would be consumed in this portion of evolutionary history. The true period must be much greater, and it does not seem unreasonable to suppose that 500 to 1,000 million years may have elapsed since the birth of the moon. Such an estimate would not seem extravagant to geologists who have, in various ways, made exceedingly rough determinations of geological periods.

As far as my knowledge goes I should say that pure geology points to some period intermediate between 50 and 1,000 millions of years, the upper limit being more doubtful than the lower. Thus far we do not find anything which renders the tidal theory of evolution untenable.

But the physicists have formed estimates in other ways which, until recently, seemed to demand in the most imperative manner a far lower scale of time. According to all theories of cosmogony, the sun is a star which became heated in the process of its condensation from a condition of wide dispersion. When a meteoric stone falls into the sun the arrest of its previous motion gives rise to heat, just as the blow of a horse's shoe on a stone makes a spark. The fall of countless meteoric stones, or the condensation of a rarefied gas, was supposed to be the sole cause of the sun's high temperature.

Since the mass of the sun is known, the total amount of the heat generated in it, in whatever mode it was formed, can be estimated with a considerable amount of precision. The heat received at the earth from the sun can also be measured with some accuracy, and hence it is a mere matter of calculation to determine how much heat the sun sends out in a year. The total heat which can have been generated in the sun divided by the annual output gives a quotient of about 20 millions. Hence it seemed to be imperatively necessary that the whole history of the solar system should be comprised within some 20 millions of years.

This argument, which is due to Helmholtz, appeared to be absolutely crushing, and for the last forty years the physicists have been accustomed to tell the geologists that they must moderate their claims. But for myself I have always believed that the geologists were more nearly correct than the physicists, notwithstanding the fact that appearances were so strongly against them.

And now, at length, relief has come to the strained relations between the two parties, for the recent marvelous discoveries in physics show that concentration of matter is not the only source from which the sun may draw its heat.

Radium is a substance which is perhaps millions of times more powerful than dynamite. Thus it is estimated that an ounce of radium would contain enough power to raise 10,000 tons a mile above the earth's surface. Another way of stating the same estimate is this: the energy needed to tow a ship of 12,000 tons a distance of six thousand sea miles at 15 knots is contained in 22 ounces of radium. Other lines of argument tend in the same direction.

Now we know that the earth contains radio-active materials, and it is safe to assume that it forms in some degree a sample of the materials of the solar system; hence it is almost certain that the sun is radio-active also.

This branch of science is as yet but in its infancy, but we already see how unsafe it is to dogmatize on the potentialities of matter. It appears, then, that the physical argument is not susceptible of a greater degree of certainty than that of the geologists, and the scale of geological time remains in great measure unknown.

Only a few thousand stars are visible with the unaided eye, but photography has revealed an inconceivably vast multitude of stars and nebulæ, and every improvement in that art seems to disclose yet more and more. It seems useless to consider whether the number of stars has any limit, for infinite number, space, and time transcend our powers of comprehension. We must then make a virtue of necessity, and confine our attention to such more limited views as seem within our powers.

A celestial photograph looks at first like a dark sheet of paper splashed with whitewash, but further examination shows that there is method in the arrangement of the white spots. Thus there is order of some sort in the heavens, and, although no reason can be assigned for the observed arrangement in any particular case, yet it is possible to obtain general ideas as to the succession of events in stellar evolution.

Besides the stars there are numerous streaks, wisps, and agglomerations of nebulosity, whose light we know to emanate from gas. Spots of intenser light are observed in less brilliant regions; clusters of stars are sometimes imbedded in nebulosity, while in other cases each individual star of a cluster stands out clear by itself. These and other observations force on us the conviction that the wispy clouds represent the earliest stage of development, the more condensed nebulæ a later stage, and the stars themselves the last stage. This view is an agreement with the nebular hypothesis of Laplace, and we may fairly conjecture that chains and lines of stars represent pre-existing streaks of nebulosity.

Change is obviously in progress everywhere, as well in each individual nebula and star as in the positions of these bodies relatively to one another. But we are unable even to form conjectures as to the tendency of the evolution which is going on. This being so, we cannot expect, by considering the distribution of stars and nebulæ, to find many illustrations of the general laws of evolution which I have attempted to explain; accordingly I must confine myself to the few cases where we at least fancy ourselves able to form ideas as to the stages by which the present conditions have been reached.

Up to a few years ago there was no evidence that the law of gravitation extended to the stars, and even now there is nothing to prove the transmission of gravity from star to star. But in the neighborhood of many stars the existence of gravity is now as clearly demonstrated as within the solar system itself. The telescope has disclosed the double character of a large number of stars, and the relative motion of the pairs of companions has been observed with the same assiduity as that of the planets. When the relative orbit of a pair of binary or double stars is examined, it is found that the motion conforms exactly to those laws of Kepler which prove that the planets circle round the sun under the action of solar gravitation. A leading characteristic of all these double stars is that the two companions do not differ enormously in mass from one another. In this respect these systems present a strongly marked contrast with that of the sun, attended as it is by relatively insignificant planets.

In the earlier part of my address I showed how theory indicates that a rotating fluid body will as it cools separate into two detached masses. Mathematicians have not yet been able to carry their analysis far enough to determine the relative magnitude of the two parts, but as far as we can see the results point to the birth of a satellite whose mass is a considerable fraction of that of its parent. Accordingly See (who devotes his attention largely to the astronomy of double stars), Alexander Roberts, and others consider that what they have observed in the heavens is in agreement with the indications of theory. It thus appears that there is reason to hold that double stars have been generated by the division of primitive and more diffused single stars.

But if this theory is correct we should expect the orbit of a double star to be approximately circular; yet this is so far from being the case that the eccentricity of the orbits of many double stars exceeds by far any of the eccentricities in the solar system. Now See has pointed out that when two bodies of not very unequal masses revolve round one another in close proximity the conditions are such as to make tidal friction as efficient as possible in transforming the orbit. Hence we seem to see in tidal friction a cause which may have sufficed not only to separate the two component stars from one another, but also render the orbit eccentric.

I have thought it best to deal very briefly with stellar astronomy in spite of the importance of the subject, because the direction of the changes in progress is in general too vague to admit of the formation of profitable theories.

We have seen that it is possible to trace the solar system back to a primitive nebula with some degree of confidence, and that there is reason to believe that the stars in general have originated in the same manner. But such primitive nebulæ stand in as much need of explanation as their stellar offspring. Thus, even if we grant the exact truth of these theories, the advance toward an explanation of the universe remains miserably slight. Man is but a microscopic being relatively to astronomical space, and he lives on a puny planet circling round a star of inferior rank. Does it not, then, seem as futile to imagine that he can discover

the origin and tendency of the universe as to expect a housefly to instruct us as to the theory of the motions of the planets? And yet, so long as he shall last, he will pursue his search, and will no doubt discover many wonderful things which are still hidden. We may indeed be amazed at all that man has been able to find out, but the immeasurable magnitude of the undiscovered will throughout all time remain to humble his pride. Our children's children will still be gazing and marveling at the starry heavens, but the riddle will never be read.

PLANT FOSSILS: THEIR FORMATION, COLLECTION, AND PRESERVATION.

THE collection and the study of plant fossils are not very popular, because of the general though erroneous impression that the securing of specimens is a matter

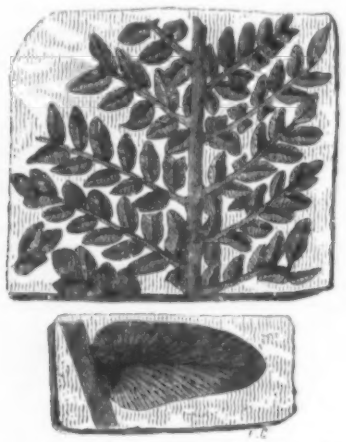


FIG. 1.—FOSSIL FERNS OF THE COAL MEASURES.

of chance and their identification very difficult. It is true that they are apt to be less striking and complete than animal fossils, but on careful examination they are found to excel the latter in fineness of detail and preservation of original structure. Their lack of variety, too, is only apparent. Their variations have escaped the notice of their few collectors.

Plant fossils are formed in various ways. A leaf falling on soft clay produces a mold of itself, and pulverulent or semi-liquid matter, deposited after the leaf has rotted, forms, on hardening, a cast which reproduces every detail of the surface of the leaf. Fossils of this type are characterized by the entire absence of organic remains and by having the impression in relief on the under surface of strata.

Again, vegetable débris may fall into a stream filled with mineral matter in suspension and be deposited with this. Thus the fragments of plants become enveloped in a magma of clay, sand or calcareous earth, which molds them with exactness. Some of these molds contain organic matter, carbonized or reduced to humus; in others the organic matter has been replaced by various minerals, and still others are empty. Plants imprisoned in permeable formations are generally converted into a sort of coal, containing humic acid. Occasionally parts of plants are preserved so well that they resemble dried specimens, but even in this case only the epidermis remains intact, while the parenchyma shows no trace of organized structure. Usually the epidermis is carbonized, also, and the flattened mold contains only a thin sheet of coal, in which, however, evidence of structure can be detected by appropriate means. From very porous sedimentary rocks the organic matter may be completely burned out by air dissolved in water, so that the plant is represented only by the empty mold. Or the void may be filled with infiltrated minerals which form a cast of the plant. Such casts may consist of silicate of magnesia, bisulphide of iron, carbonate of copper (in zechstein), or hydrated ferric oxide (in mottled sandstone). All

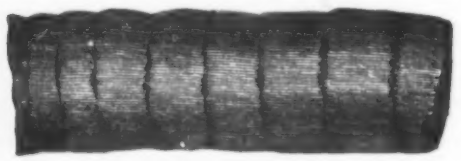


FIG. 2.—FOSSIL CAST OF CALAMITE.

these result from chemical changes occurring in infiltrated solutions. Oftener, however, the organic matter has been replaced directly by clay or sand deposited from suspension, which has subsequently hardened.

Even at the present day plants which grow beside streams fed by mineral springs may become incrusted with a deposit which increases in thickness until the plant is inclosed in a solid block. The same process went on in the past but, in many cases, the plant has been gradually consumed, leaving a hollow mold. When the incrustation is calcareous it is easy to reproduce the form of the plant by filling the cavity with plaster or wetted wax and dissolving the imprisoning stone in dilute hydrochloric acid. Silicious rocks, unfortunately, cannot be treated in this way. The cavity is filled by exposing a small orifice and soaking the piece of stone in melted wax until the evolution of bubbles ceases. These wax casts reproduce the most varied and delicate organs, even entire flowers, and are very lifelike if the wax has been colored by an admixture of oxide of chromium. As they are exceedingly fragile they should be mounted on cards and inclosed in glass tubes.

In amber, the hardened resin of certain conifers of the Miocene period, are found parts of plants preserved so perfectly that they appear as if freshly gathered. Gaeppert has described more than two hundred species.

In still another type, the fossilizing liquid was a very dilute solution which penetrated gradually to the innermost cells, transforming the plant to a petrifaction, often of extreme hardness. These petrifactions, which may consist of silica, carbonate of lime, phosphate of lime or carbonate of iron, are as valuable for anatomical study as living plants.

Finally, a great many plants have been preserved in the state of peat, lignite and soft coal. (Figs. 1, 2, 3.)

The most abundant plant fossils, however, consist of relief impressions or entire molds. These may be sought, profitably, in quarries, railway cuts and natural ravines. As their position is generally determined by the stratification, they may be laid bare by splitting the rock fragments along their natural cleavage planes, near protruding stems or other indications of their presence. In limestones and sandstones the plant itself is usually absent. When an impression is thus found by cleavage both pieces of the stone should be preserved. They bear intaglio impressions of opposite sides of the plant, not, as is often supposed, a relief and an intaglio of the same side. Impressions in relief are found only on the lower surfaces of strata.

In the coal fields the collector's attention should be confined to the heaps of refuse, consisting of the rocks which alternate with the coal seams, for the latter seldom contain easily recognized plant fossils.

The surface of the rock fragment, perhaps, shows no impression, but is crossed by glossy black lines. These represent layers of vegetable matter and, also, the natural cleavage planes, along which the stone may be split with ease. No more of the cut surface should be cleaned than is necessary to determine the character of the impression. The rest of the carbonaceous layer should be left to be examined under the microscope for traces of organized structure.

After the superfluous rock has been chipped away the specimens should be carefully wrapped in several

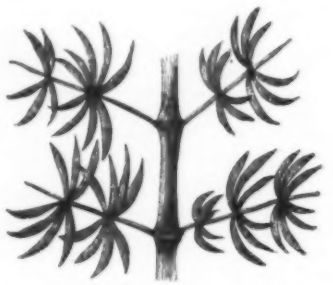


FIG. 3.—FOSSIL PLANT (ANNULARIA).

thicknesses of paper. If packed for shipment they should stand on edge and be pressed together tightly to prevent rubbing. Specimens which contain pyrites should be protected from oxidation by several coats of a weak solution of wax or paraffine in benzine or, preferably, of solid Canada balsam in alcohol. If the carbonaceous deposit is too thin to be of use in determining structure the impression may be brushed lightly with wax, which will make it show more distinctly, in glossy black on the dull background of the stone.

Some schistose and other rocks disintegrate on exposure to the air. This is caused by rapid and uneven drying and may be prevented by drying slowly, without access of heat or drafts.

Impressions in recent molds and clays usually contain much organic matter, more or less decomposed. These vegetable remains, when dry, are easily removed from the stone. If they are worth preserving they should be brushed, before drying, with gum water or a three per cent hot solution of gelatine.

Petrifactions composed of silica, carbonate of lime or carbonate of iron are generally more or less imbedded in magmas of similar composition, so that the genus and species must be determined from fractures and protruding parts.

In collections, specimens are mounted on cards with a thick paste of gum arabic and flour, or chalk, and are displayed, in cardboard boxes, either open or covered with glass.

The tools of the fossil hunter include a chisel for making the groove which determines cleavage, a steel point of square section for picking out, cleaning and marking specimens, a hammer with a similar point, used with the chisel in disengaging specimens from conglomerates, a hammer with a wedge at one end for splitting schistose rocks, and a saw for cutting soft materials.—La Science au XX Siècle.

THE LAW OF ERRORS.

THE dispersion, upon a target, of the points of impact obtained by firing a large number of shots with the same weapon, in employing the same breech-sight and in aiming at the same point, occurs according to certain known laws.

Such points of impact group themselves symmetrically around a center called the "mean point." The density of the shots continues to diminish in measure as the marksman moves farther away from the mean point. The mean point of a grouping is obtained by the intersection of two perpendiculars, $H\,H'$, $V\,V'$, each of which divides the number of points of impact into two equal parts. (Fig. 1.)

If, through a line, $X\,X'$, parallel with $H\,H'$, we divide into two equal parts the number of shots that are found above $H\,H'$, we shall determine a band, X, that contains a quarter of the shots, and the width, $P\,A$, of which is what is called the probable dispersion.

If, starting from this mean point, and, on each side thereof, we draw four bands of which the width is equal to $P\,A$, that is to say, to the probable dispersion, experiment and calculation will show that the contents of such bands are respectively 25/100, 16.1/100, 6.7/100, 1.8/100 of the shots fired.

We thus find as the contents of such bands the following numbers, which are easier to remember, but are slightly less exact: 10/40, 6/40, 5/40, 1/40.

A band of which the width is four probable dispersions on one side and the other of the mean point, will

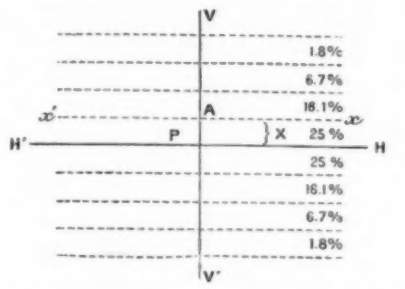


FIG. 1.—DETERMINATION OF THE PROBABLE SCATTERING.

contain 99.2/100 of the shots fired, that is to say, the majority of the shots, the abnormal shots not being comprised in the band.

These laws of dispersion are not peculiar to firing solely, but are found in the measurement of any dimension. In fact, to fire a ball and not strike the point aimed at is to commit an error of the same nature as measuring a distance by pacing and not find the exact distance, and of the same nature as measuring a given height by our visual organs and imperfect instruments and not finding the measurement true. The following very easily tried experiment permits of ascertaining the accuracy of the laws of dispersion applied to the measurement of heights.

By the eye, divide the thickness of a large book into two equal parts with the blade of a penknife, take note of the page found, and repeat the operation forty times, and then compare the results. The forty page-numbers found upon performing this experiment have been classified by order of increasing values, as shown in Fig. 2. The numbers 479, 490, and 499 divide these 40 numbers into four series of 10 numbers each; 490 corresponds to what we have called the mean point in firing; the $490 - 479 = 11$ corresponds to the greater probable dispersion, and the difference $499 - 490 = 9$ corresponds to the less probable dispersion. But these two dispersions must be equal, and, if they are not so, it will be due to the fact that the experiment has not

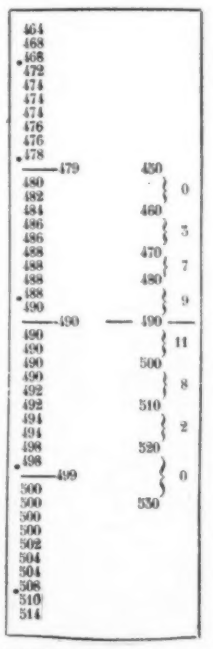


FIG. 2.—RESULTS OF THE EXPERIMENT.

been performed a sufficiently large number of times.

Let us give this probable dispersion the intermediate value of 10, and let us form a table in carrying to one side and the other of 490 a succession of numbers each containing 10 units less than the preceding on the one side and 10 units more on the other. It is easy to see, in the first place, that all the page numbers are comprised within an interval of four probable disper-

signs counted upon one side and the other of the mean point. The interval from 450 to 530 comprises all the numbers from 464 to 514.

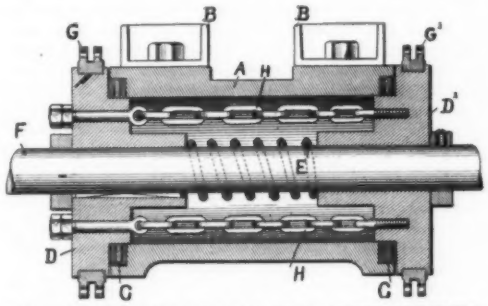
Besides, if we count the number of the numbers comprised in each dispersion, we shall find the figures 0, 3, 7, 9, 11, 8, 2, 0, which closely approach the following: 1, 5, 6, 10, 10, 6, 3, 1; which indicate the theoretical contents of the different bands of a probable dispersion in firing.

The book used for this experiment had 988 pages, the half of which is 494. The average of the measurements does not coincide with the true measurement, just as in firing the mean point of the grouping does not coincide with the point aimed at.

When, in the measurement of any dimension whatever, we repeat the operation several times in order to obtain an average, it is an error to think that we have surely approximated to the true measurement. The first ball may be much closer to the point aimed at than the mean point will be. The first measurement of a dimension may be much nearer the truth than will be the average of several measurements. Nevertheless, it will be right to look for an average, since this is the only way surely to avoid great dispersion.—Translated for the SCIENTIFIC AMERICAN from La Nature.

AN EMERGENCY BRAKE FOR AUTOMOBILES.

WE illustrate herewith an emergency brake for motor cars which has lately been brought out by Messrs. Dickins, Bowen, and Broadfoot, of St. Stel Chambers, Birmingham, England. The illustration shows a sectional elevation of the arrangement. *A* is a hollow metal cylinder, firmly attached to the frame of the car, parts of which are shown at *BB*, in such a position that the driving shaft or axle, *F*, to be acted upon passes concentrically through the length of the cylinder. *D* is a disk keyed to the shaft or axle at one end of the cylinder. *D*¹ is another disk at the opposite end of the cylinder not keyed to the shaft. The two disks are held together by the chains, *HH*, while the helical spring, *E*, keeps the disks at their respective distances, giving the necessary clearance when not in use for the working in unison with the axle or shaft.



AN EMERGENCY BRAKE FOR AUTOMOBILES.

and giving the release after use. *CC* are anti-friction rings, to assist in eliminating any shock. *GG*¹ are brake shoes acting on either disk; the one on the disk keyed to the shaft gives a strong effective brake for all ordinary purposes, while the other, on the free disk, is for operating the emergency brake, which is semi-automatic, and acts in the following manner: When the brake *G*¹ is applied to the free disk by the slight pressure of a foot or hand lever, it causes the disk to lag behind the one at the opposite end of the cylinder, which is keyed to the shaft, having a slight lateral movement on the key. As soon as the free disk has lagged sufficiently to cause the twisting of the chains *HH* to take up the clearance, the fixed cylinder, *A*, is clamped firmly between the two disks, and any further tendency of the shaft to revolve only jams the tighter, so the whole apparatus is locked as one solid mass. The effect of this sudden stop would be a great shock without anti friction rings *C C*; so these rings are inserted to eliminate this, which can be done to any extent by adding or decreasing the number of rings. For the average condition of a light car three rings on either side produce, the makers claim, a rapid locking of the shaft, with practically an absence of shock; in these circumstances the time required for absolutely stopping the shaft would be one revolution. As can be judged from the illustration, the apparatus works effectually in either direction. Therefore, all that is necessary to stop running backward on an incline is to apply the emergency brake lever, and the car, running backward from rest, the applied emergency brake would act as a sprag, at only a very slight angle of displacement—say, one-fifth of a revolution of the shaft—safely holding the car on the steepest gradient, and enabling the forward speed to be put in at once. The device can be applied to all classes of vehicles, and is stated to be specially suitable for use on motor 'buses.—The Motor-Car Journal.

Experiments with Borax in Food.—The work of the Bureau of Chemistry in the study of the effect upon digestion and health exerted by preservatives, coloring matter, and other substances added to food has been continued by the Department of Agriculture. The great quantity of data secured in this work in relation to the effect of borax has been compiled and is now being published. These studies of the effect of borax have led to certain definite conclusions which are of the utmost interest to manufacturers of food products into which borax has often been introduced, and to the consuming public.

TWO HERMIT SPIDERS.*

By C. E. HUTCHINSON.

IN Southern California lives a spider (*Apostichus clathratus* Simon†) allied to, and closely resembling, the trapdoor spider of that region, though it is much smaller. It is found in the hills, under tall bushes, living in the ground, in a tunnel of its own making; but the nest, unlike that of its famed relative, possesses no door.

Instead of making the silk lining of its tunnel paperlike, like that of the trapdoor spider referred to, it weaves one loosely which is fastened to the wall by frail threads. The spider traverses this tube readily, but the venturesome foe that enters it finds itself quickly entangled. A struggle to free itself causes the fabric to fall away from the wall and enswathe the intruder, which escapes with difficulty or not at all.

Preceding an interval of retirement such as the spider enters upon at certain seasons, and frequently after a feast, it spins a few loose threads from one side of the tube to the other, for some distance along the tube, commencing near the entrance, and these serve further to discourage designing insects, so that, withal, it is well protected from its principal enemies.

Four years ago, several of these spiders were placed in a box of earth that they might be conveniently studied, and some of them are alive now, occupying the original nests, though at no time have they been restrained.

The spider does not at any time leave its nest in search of food. Instead, it lies in wait, in the mouth of the tunnel, until an insect approaches, when it rushes out and falls upon it. A few inches is as far as it can be induced to go, for when no farther away than that it becomes easily confused and finds its way back often with difficulty.

The young remain in the old nest for several years. During this prolonged occupancy the mother remains barren, an advantageous condition considering the size of the nest and the very limited area within which food for the household must be procured.

It is not uncommon to find as many as twenty young, each one-fifth the size of the mother spider, living, presumably harmoniously, in the old nest.

Their final departure upon an independent existence begins no prolonged journey. The new nests are made

TRAPDOOR SPIDER SEIZING A CATERPILLAR.

The drawing shows the characteristic attitude with reference to the trapdoor, beyond which the spider never goes.

within a few inches of the old one, so that the spider appears to live in colonies. A score or two may be found in a square yard.

Notwithstanding its recluseness it must not be placed in the first rank among hermits, for we have the trapdoor spider, *Bothriocyrtum Californicum*, which does not at any time during its life of ten or perhaps twenty years emerge completely from its nest for any purpose whatever.

The foregoing in either case has reference to the female, though it may also apply to the male up to maturity.

The silk egg-bag that the trapdoor spider makes is shaped like a hammock and hangs from the wall, down in the lower and sub-horizontal end of the burrow. It is an extremely frail fabrication, composed of two sheets of silk which are united at their edges. The silk is of wonderful whiteness. Upon the lower sheet the eggs are deposited in a glutinous mass which is quickly covered with the second sheet. The young emerge from the bag in June—two hundred in number. The abdomen of the young spider contains a store of nutritive matter sufficient to sustain the little one until the winter rains come.

In a week or two the spiderlings are able to crawl up and down the wall of the maternal domicile, which they do to find the temperature most to their liking.

There is no evidence that the mother spider takes the least notice of them. They remain within the nest during the summer, never trying to venture forth until the first heavy rain of winter; then as the wall dampens they become restless, and gather just beneath the door. The heavy earthen door and the stout silk lining of the nest are insuperable obstacles preventing their escape, and but for the mother spider's assistance they would perish within the nest. With the ending of the rain she raises the door, and the young crawl out.

Each young spider, as it leaves the nest, is guided by a single impulse, that of gaining a home of its own with the least delay possible. Some go no farther than a few inches from the old home, others travel a few feet, but in either case a short time suffices to find a satisfactory location, and within a few hours thereafter the untaught builder is able to close the door to its own habitation, though to finish the tunnel requires a day or two.

The trapdoor that this spider makes has often been described and has as often excited admiration. Should a door be removed in spring or in winter a new one is made at once, but when one is removed at any other time the task is deferred, for, except during the seasons mentioned, the spider is inactive.

However, the tunnel must be closed, which is quickly and easily done by weaving across it a web, about one-half inch below the rim. The part above the obstruction is soon filled with loose particles blown in by the wind, which conceal the entrance effectually. The obstruction, at whatever time made, remains until winter, as the hermit requires no food during the summer.

A. TRAPDOOR SPIDER WITH LEGS REMOVED TO SHOW PREHENSILE ORGANS.

pf, Poison fang; md, mandible; mo, mouth; e, eyes; B, position of fang when not in use.

The spider is active as late as May, and if the earth is too dry and hard at that time to be worked in the usual manner, a door may be made of bits of weeds and grass fastened together with silk. But if all material suitable for that purpose be removed from about the entrance for a distance of three inches, the spider will not avail itself of any that lies beyond, however much there may be in sight.

The experiment that brought out the fact just stated was one of several, fully as indicative, that were performed to prove what has been stated in the foregoing, that the female spider does not at any time during its life leave the one dark cell within which it incarcerates itself in its infancy. So remarkable is this peculiarity, that it seems appropriate to add that the spider has been closely studied for several years for evidence on this particular point. The male, which appears to be a very pronounced polygamist, is believed to be no less a recluse up to the time of his maturity. All growing spiders shed their skin periodically, an operation that, by reason of its tragic aspect, is never devoid of interest. With this spider the molt discloses a striking change of color, more remarkable because of its fugacity. The abdomen at all times is almost black. Just before the molt the limbs and thorax, also, are nearly black, though the short hairs sparsely covering them are brown-black. Immediately after the molt the body, exclusive of the abdomen, is ivory white, though the hairs upon every part are black. The carapace, or back of the thorax, is practically nude. This very striking contrast soon disappears for in a few hours a blue-green tint appears in the white, and rapidly grows darker until, at the end of a week, the parts affected are green-black.

By reason of its inactive life the spider requires little food. Nutriment in excess of its immediate requirement is believed to be stored up within the body, by vital process, where it is available in time of shortage, and during the season of abstinence which it yearly undergoes.

To obtain its food the spider takes a position just beneath the door and there remains, often by the hour, as motionless as the wall to which it clings. The door is raised a mere trifle, being supported in that position by the watcher. Too violent a disturbance causes the door to be closed hastily, but the tread of a caterpillar is sufficient to fill the spider with animation.

When an insect crawls by not less than three inches from the opening it is perfectly safe, but should it approach nearer than that the spider springs forth, like a jack-in-a-box, and pierces it with its two needle-pointed fangs. Within a second or two the prey is seized and dragged into the tunnel, over which the door closes automatically.

In springing forth the spider carefully avoids pass-

APOSTICHUS CLATHRATUS.—ADULT FEMALE.

ing beyond its own length, and the door rests finally upon the abdomen so that it is free to retreat backward into the tunnel without inconvenience. Innumerable observations have disclosed no exception to this mode.

The spider's action may be perceived readily during cold nights in winter, as it moves slowly then, but in sunlight on hot days it moves with remarkable rapidity. The position of the prey is believed to be determined by sound. There is no indication that the eyes are used for that purpose, as the door is never raised sufficiently for that until the spider springs forth, when its rapidity appears to preclude the possibility of its altering its initial course in the brief time consumed.

* Specially prepared for the SCIENTIFIC AMERICAN SUPPLEMENT.

† For the name of this spider I am indebted to Nathan Banks, Washington, D. C.

OLD AGE.*

By ELIE METCHNIKOFF, Subdirector of the Pasteur Institute.

THE problem of old age is one of the most complicated and difficult found in the biological field. As it is far from being solved, it will be impossible for me to present to you a complete study with results sufficiently precise to be practically applied. On the other hand, the course of procedure which we pursue in studying this question has already been made public, and consequently contains nothing especially new.

In considering this question of old age we are beset on every side with difficulties. At what period of our life does this ultimate stadium begin; at what time ought a man to say that, having entered upon this stage of his existence he dare no longer conduct himself as an able-bodied individual? It was but a few months ago that the students of the faculty of medicine in Paris loudly and noisily protested against the decision of the Senate that had suspended the law prescribing a limit of age for the professors. "We do not want old dotards," declared these young men. It is not rare to see old scientists of very great merit remain in their chairs up to an age when they are no longer capable of assimilating scientific progress, of judging correctly concerning new advances. Their auditors readily see that they are no longer abreast with their coworkers; the old professors alone can not perceive this. As regards myself, if I had remained in my native country I would necessarily have been retired five years ago as having accomplished my thirty-five years of service.

It has for a long time been noticed that the longer one lives, the longer one desires to live. Charles Renouvier, a French philosopher, recently deceased, gave new proof of this rule. When 88 years old and feeling himself to be dying, he jotted down his impressions during his last days. This is what he wrote four days before his death:

"I have no illusions regarding my condition. I know that I am soon to die, in a week or perhaps two, and yet I have so many things to say about our doctrine. At my age one has no right to hope. One's days, or perhaps one's hours are numbered. I must be resigned. . . . I can not die without regret. I regret that I can in no way foresee what will become of my ideas. Besides I am going before I have said my last word. One always has to leave before terminating one's task. This is one of the saddest of the sadnesses of life. . . . This is not all. When one is old, very old, habituated to life, it is very difficult to die. I readily believe that young people accept the idea of death more easily than the old. When one is beyond 80 years he becomes cowardly and does not wish to die, and when one knows beyond question that death is near a feeling of melancholy pervades the soul. . . . I have studied the question in all its aspects. I know that I am going to die, but I do not succeed in convincing myself that I am going to die. It is not the philosopher in me that protests. The philosopher in me does not believe in death, it is the old man, the old man who has not the courage to face the inevitable. However, one must be resigned."

The aspect of old age is too well known for it to be necessary to describe it in detail. The skin of the face is dry, wrinkled, usually pale. The hair is white, the body more or less bent, the walk slow and difficult, the memory defective. Such are the most significant traits of the aged. It is often thought that baldness is characteristic of old age, but this opinion is erroneous, for the head begins to become bald at a comparatively early period. At an advanced age baldness follows its course, but whoever has not begun to lose his hair when young will not become bald during old age.

Stature decreases with age. According to numerous measurements men lose, between 50 and 85 years, more than 3 centimeters (3.166), women still more (4.3 centimeters). Sometimes this loss may reach 6 or even 7 centimeters.

Weight also diminishes during old age. According to Quételet, the maximum weight of men is attained at 40 years of age, of women at 50. From 60 years onward weight diminishes, and at 80 years this loss amounts, on the average, to 6 kilogrammes.

The diminution in the height and weight of the body indicates a general atrophy of the organism in old age. Not only do the soft parts, such as the muscles and the viscera, become lighter, but even the skeleton loses weight in the old because of the diminution of mineral matters. This decalcification during old age, extending to all parts of the skeleton, causes a brittleness of the bones of the aged, which often leads to fatal results. One of the greatest representatives of medical science during the nineteenth century, Virchow, at the age of 82 years, in descending from a tramway, made a false step and broke the neck of his femur. In spite of all the attention that could be given him he died of the general exhaustion of forces after remaining several months in bed. Princess Mathilde fell in her chamber. This fall, which would have had no bad result in a young person, caused in this woman, 83 years old, a fracture of the neck of the femur. As in the case of Virchow a prolonged confinement to bed led to general malnutrition which terminated in death. This part of the skeleton, the neck of the femur, becomes particularly brittle in the old because of osseous atrophy.

The muscles are also much subject to atrophy during old age. They lose in volume, the muscular tissue becomes paler, the fat between the muscular fasciculi diminishes in quantity and sometimes almost completely disappears. Movements also become slower and muscular force diminishes. Measurements of the force of the hand and of the trunk, made by means of dynamometers, show a progressive diminution in the old. This enfeeblement is more pronounced in men than in women.

The volume and the weight of the viscera also diminish, although in a different ratio for different organs. In order to explain the general atrophy of the body in old age an attempt has been made to ascertain the intimate structure of the organs and tissues of the aged. The visible manifestations of our organs represent the total of the functions of the microscopic elements that enter into their constitution. In order to understand the formation of the calcareous deposits upon which Paris is situated, and by aid of which its houses are constructed, it is necessary to consider the properties of the mollusks that have formed the shells which have accumulated and become cemented together to produce the stones. In the same way, in order to judge of the senile alterations of our body, it is indispensable that we should study the changes that occur in the cells that compose it.

A great number of these elements are continually being lost. From the surface of our epidermis are detached minute scales composed of a quantity of flat desiccated cells that have become incapable of protecting our skin. The secretions of the mucous membranes daily carry away great numbers of the cells that make up those membranes. There is, therefore, a considerable wear of the microscopic elements of our body which must be reconstituted in order to maintain its equilibrium.

Under these conditions it was quite natural to ask whether the reparation of our cells is as well effected in the old as in those of adult life. This question arose all the more naturally because there are known examples of very low organisms that multiply by division, and which, after a considerable number of generations, finally fall into a state of exhaustion in which reproduction becomes gradually slower and more difficult, and may even cease altogether. This state of debility, which has been compared to senile atrophy, yields to certain influences, such as the conjugation of two exhausted individuals, or even to improved nourishment.

But since among inferior organisms, which resemble so much the cellular elements of our body, reproduction becomes exhausted at the end of a certain period, we are led to suppose that the same law may also apply to the senile atrophy of our own organism. Therefore, numerous scientists affirm that old age finally results because it is impossible for an organism to repair the cellular losses by the formation of a sufficient number of new elements—that is to say, because of the exhaustion of the reproductive faculty.

One of the scientists who have more especially concerned themselves with general questions, Weismann, expresses himself on this subject in a very categorical manner. According to him, the senile degeneration that ends in death does not depend on the wearing away of the cells of our organism but rather upon the fact that cellular proliferation, being limited, becomes insufficient to repair that loss. As old age appears in different species and different individuals at various ages, Weismann concludes that the number of generations that a cell is capable of producing differs in different cases. It is, however, impossible for him to explain why, in one example, cellular multiplication may stop at a certain figure, while in another it may go much further.

This theory appears so plausible that no attempt has been made to support it by precise facts. We even see, in the most recent attempt at a theory of old age, by Dr. Bühler, the thesis of the exhaustion of the reproductive power of the cells accepted and developed without sufficient discussion. It can not be denied that it is during embryonic life that cells are produced with the greatest activity. Later on this proliferation becomes slower but it nevertheless continues to occur throughout the course of life. Bühler attributes the difficulty with which wounds heal in the aged, precisely to the insufficiency of cellular production. He also thinks that the reproduction of the cells of the epidermis which are to replace the desiccated parts of the skin diminishes notably during old age. According to this author it is theoretically easy to predict the moment when cellular multiplication in the epidermis must completely cease; as the desiccation and desquamation of the superficial parts continues without cessation it becomes evident that it must finally result in the total disappearance of the epidermis. The same rule is applicable, according to Bühler, to the genital glands, the muscles, and all sorts of other organs.

These theoretical considerations do not, however, agree with well-known facts which speak but little in favor of a general diminution of cellular proliferation in old age. The hairs and the nails, which are excrescences of the epidermis, keep on growing throughout the entire life, thanks to the reproduction of the cells which constitute them. There is no arrest at all in the development of these parts even in the most advanced age. Far from that. We know that the hair that covers certain portions of the body increases in quantity and length in the old. In certain inferior races like the Mongols, the mustaches and the beard do not grow abundantly until advanced life, while young people have but small mustaches and very little or no beard. In women of the white race the same phenomenon occurs. The delicate and almost imperceptible down that covers the upper lip, the chin, and the cheeks of young women is transformed into veritable hair which forms the mustaches, beard, and whiskers of old women. Dr. Pohl, a specialist in everything that concerns the hair, measured the rapidity of growth of hair under different circumstances. He found that in an old man of 61 years the hairs of the temples grew 11 millimeters in a month. But these hairs, in the same regions, in boys of from 11 to 15 years grew in the same time 11.8 millimeters, which represents almost the same figure.

There is therefore in the three subjects studied by Dr. Pohl no considerable diminution in the cellular growth in the old, in spite of the great difference in age. It is true that this observer showed that the hair of a young man between 21 and 24 grew at a rate of 15 millimeters per month, while in the same individual at the age of 61 years the rate lowered to 11 millimeters; but this slowing down of the growth of the hair was only apparent. In fact, the first figures related to hair from different regions of the hairy scalp, while the second related only to the hair of the temples. Now it is well established by Dr. Pohl himself that in the latter place the hair grows more slowly than elsewhere. On the other hand, in boys from 11 to 15 years old, studied by this observer, the rapidity of development of the hair was always shown to be less than 15 millimeters. It was often even below the 11 millimeters found in the man 61 years old.

In spite of the abundant growth of the hair in old age, these parts undergo a senile degeneration; that is to say, the loss of pigment. This blanching is doubtless an atrophic phenomenon which is not due to an arrest of cellular multiplication, but to the disappearance of colored granulations.

Let us now cast a glance at some other manifestations of old age. The debility of muscular movements is connected with modifications in the structure of the muscular fibers which also do not indicate an absence of reproductive power. The fascicles which form the muscles undergo a veritable atrophy, for they become much thinner than in their normal state. Besides there is deposited in their interior a quantity of fatty granulations, and, what specially merits attention, the nuclei of the muscular fibers show a very abundant multiplication, forming masses arranged in long series. Douaud, who has published a thesis upon the modifications of muscles in old age, remarks in this connection that the endogenous multiplication of muscular nuclei in old age is very active and that it takes place in exactly the same way as in the embryo. In this example of senile atrophy we are far then from finding a cessation of reproductive power in the cells.

As regards the brittleness of the bones in old people, this is also caused by cellular multiplication which produces large cells capable of destroying the osseous substance and making the bones spongy.

Detailed microscopic observation of senile organs has shown in a direct manner the existence of cellular multiplication. Thus Sackaroff observed it in the lymphatic ganglia of old persons, and among others in a man 102 years old. The few data just cited suffice to enable us to reject the theory that old age is caused by the exhaustion of the reproductive faculty of the cells. We must seek for another more conformable with the well-established facts of senile degenerescence. Without entering upon new details, let us try to comprehensively survey those we have already given. What common features connect the blanching of the hair with the atrophy of muscular fibers and the brittleness of the bones of the aged?

The loss of colored granulations in the hair is due to the setting free of a quantity of wandering cells which seize the pigment and transport it elsewhere, leaving the hair decolorized. In the atrophy of the muscles there is a multiplication of the nuclei and of the substance that surrounds them. As in the hair there are cells which devour the pigment, so in the muscles there are the multiplied elements we have just cited which devour the contractile substance. In senile bone, the osseous substance is destroyed by the giant cells mentioned above. In the cells of the senile organs just studied the general and essential phenomena consist, then, in the destruction of parts useful to the organism by wandering cells that present some traits in common with each other. They are voracious cells belonging to the category of elements designated under the generic name of macrophages. Certain macrophages remove the pigment of the hair, certain others destroy the osseous lamellæ, others still devour the contractile substance of muscles.

It is easy to prove that this activity or rather superactivity of the macrophages is observed in the most diverse organs of the aged. It is found in the brain, where the cells are in the act of devouring the most noble elements of our organism. In the kidneys and the liver of old persons there are found collections of macrophages that cause the secretory cells of those organs to disappear, thus occasioning phenomena of atrophy of very great importance.

After having destroyed the noble elements of the aging organism, such as the nervous, renal, and hepatic cells, the macrophages become fixed in place and are transformed into connective tissue without ever being able to supply the place of the precious elements that have disappeared. It is in this way that there is set up in the aged that main factor of our premature decay, sclerosis of the organs. A study of the special phenomena of old age shows, then, that they arise from a cellular activity that brings about the destruction of the noble elements and the superiority of the macrophages. The latter, which in a normal state act as

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protectors of the organism against the invasion of microbes, at last themselves invade the most useful parts. There is produced in our body by the advance of age something analogous to what occurs in the old age of certain peoples when the army, intended to protect the state against exterior enemies, turns against the citizens of its own country.

In this invasion of the senile organs by the macrophages there sometimes occurs a veritable struggle between these voracious cells and our noble elements. Weakened by diverse causes these elements show signs of degeneration in the form of deposits of fat or of pigment. In these conditions of inferiority the cells of the brain, of the kidney, or of the liver more readily become a prey to the macrophages, whence results the loss of intelligence and the disorders of digestion and of the emunctories which are so common among old people.

But in other cases there can not be any serious question of a struggle between two categories of living elements. When the macrophages devour the pigment of the hair, or, indeed, destroy the osseous substance, there occurs rather an aggression of the macrophages upon inert parts that are incapable of defending themselves.

We have tried to show that the theory of the mechanism of old age which attributes a preponderating part to the attack on the valuable elements made by the macrophages is not a mere plausible speculation, but rests on numerous and exact facts. It would be interesting to penetrate more deeply into the causes of this drama which is being played within our own organism and which occasions such serious evils. Unhappily science is not sufficiently informed to satisfy an investigating spirit otherwise than by the aid of hypotheses.

It has often been said that old age is a kind of disease. In fact the great resemblance between these states is incontestable. Among the maladies to which an organism is subject there is a considerable group that manifest themselves in the form of atrophies. Sometimes it is an atrophy of muscles which occasions a considerable weakness in the voluntary movements and in which we find proliferation of the nuclei, as in the muscles of old people. Atrophic maladies of the kidneys and of the liver are numerous, and in these we find a disappearance of the glandular tissue and its replacement by connective tissues the same as we find in old age. Atrophy of the osseous substance produced by giant cells often occurs in the course of certain maladies. In all these examples the more profoundly we study the lesions the more we become convinced of their similarity to those which take place during old age.

Although the cause of many of the atrophic maladies is still unknown, there are nevertheless some whose origin is sufficiently established. Thus, among the atrophies of the muscles, we may cite that which is induced by the parasitism of trichinæ. The penetration of these minute worms into the muscular fascicles produces lesions that occasion multiplication of muscular nuclei and a destruction of the contractile substance.

The analogy with the atrophy of muscles is undeniable. The atrophic maladies of glandular apparatus such as the liver and the kidneys, are often occasioned by poisoning by alcohol, lead, and other chemical substances or they may be occasioned by some infectious microbic malady. Again, it is this latter cause which often leads to the destruction of the osseous substance. In certain infectious maladies like tuberculosis and leprosy the bacilli penetrate into the bones and succeed in forming there infectious foci. These bacilli are, however, incapable by themselves of dissolving and destroying the osseous substance, but the products that escape from them into the bones exercise an irritating action upon the giant cells which set to work to eat away the osseous lamellæ impregnated with lime. The tuberculous or leprous agent plays, therefore, only an intermediate part in the atrophy of the skeleton, which is immediately caused, as in old age, by the work of the giant cells designated under the name of osteoclasts.

Since the mechanism of senile atrophy is entirely similar to that of atrophies of microbic or toxic origin, it may be asked whether in old age there may not be some intervention of microbes or their poisons. May not this abnormal excitation of the macrophages that leads them to destroy all sorts of noble cells of the organism and to even attack the pigment of the hair and the osseous substance be also due to the action of certain poisons elaborated within the body? The principal source of these poisons is clearly indicated: our digestive tube contains an enormous quantity of microbes, and many of them are capable of secreting substances that are more or less toxic. Our intestinal flora resembles the flora of forests in which there are found by the side of boleti and other edible mushrooms a great number of poisonous ones. It is true that our intestine is, up to a certain point, protected against the invasion of the microbes contained in it and even against their poisonous products. We may with impunity feed animals that are quite easily affected by certain infectious maladies upon the microbes that produce those maladies. Thus guinea pigs may swallow without harm great quantities of the bacilli that produce anthrax, but if there is the least lesion in the intestinal wall the mortal malady will declare itself. The presence of infectious microbes in the digestive tube may therefore have sad results.

The intestine is likewise protected against the absorption of certain poisons. We may, for example, cause guinea pigs to swallow, without effect, many cubic centimeters of tetanic poison, a hundredth part of a drop of which injected under the skin will inevitably bring on a mortal tetanus. The intestinal wall does not, therefore, absorb the tetanic poison. There are, however, other poisons that do not follow this rule and which are easily absorbed in the intestine. Cases of poisoning by poisonous mushrooms taken for edible ones are quite frequent. Neither is there any lack of microbic poisons that traverse the intestinal wall. We see arise from time to time veritable epidemics that are serious and even fatal as a consequence of the consumption of fish, meat, or conserves spoiled by microbes. In these cases there is usually an entrance into the intestines of the botulynic bacillus, which secretes a very violent poison readily absorbed by the organism in the same way as is the poison from noxious mushrooms. The symptoms of Asiatic cholera are also produced by a toxine elaborated in the digestive tube and absorbed by the intestinal wall.

(To be continued.)

SCIENCE NOTES.

The physician of early ages was a magician and necromancer. The medicine man of savage tribes is still practising the art of incantation. It is a far cry to Æsculapius, but before his day even disease was supposed to be the work of evil spirits. In fact the most destructive swine plague that we read about in the Bible was caused by the devils which were cast out of sick men, and these devils, taking possession of the swine, caused them to rush into the sea and be drowned. The age of magicians in medicine was followed by that of the empiric, which was a great advance and led to the foundations of real science in medicine. The empiric we still have with us and always will have as long as man has idiosyncrasies. We can never tell in any individual case what the result of any certain treatment will be because we can never properly estimate the value of the individual idiosyncrasy.

The study of nerves, their connections and activities, has been begun in earnest only within the past few years, but what has been learned seems to lead to as many surprises as has any other branch of science. Only here and there is there now an investigator in this branch, but these have already found out that all nervous action is spent upon the muscles. That all are in one way or another connected with them, that each particular nerve cell has a specific function and substitution seems no more possible among them than can the eye be substituted for hearing or for tasting. At present work is being carried on to determine the functions of various parts of the brain, especially for the effects of use and disuse, the nature of exhaustion, the rate of recuperation, the source of energy and of automatic activity, what happens in sleep, in the hypnotic state, in disease, insanity, and in unconsciousness. Dr. Hall has said that the nerves are the most wonderful things in the world, and we know so little about them. Mind and thinking, conditioned by their presence and activity, on the one hand, and all expressions of them through muscular action as exhibited by motions and emotions.

The medical profession of the future will see extended and placed upon sounder scientific foundations the antitoxin theory of prevention and cure. The world owes a debt of gratitude to Pasteur and his colaborers in this and other countries for establishing the foundation, on broad scientific grounds, of the idea that immunity may be artificially, as well as naturally, produced. Jenner was the forerunner of this great school of medicine, but his practice was absolutely empirical. Neither he nor his followers had any idea whatever of the manner in which vaccination renders the subject practically immune to smallpox. Advanced medical science has revealed the fact, however, that not only smallpox, but many other deadly diseases owe their toxic development to the compounds produced in the system chemically allied with the nitrogenous constituents of the body. The moment these poisons become dominant in the system nature makes an effort to eliminate them or to neutralize them. In other words, the toxic body is met and combated by the antitoxic body. One of the greatest triumphs of the science of chemistry has been the determination of the character both of toxic and of antitoxic substances and the development of the method of producing them both, especially the antidote.

Although the inspection of food products has not yet extended over two years, it is already seen that most beneficial results have been obtained. Fortunately, during all this time no recourse has been had to the courts, either to secure the enforcement of the act or to prevent it. In nearly all cases importers have been satisfied with the evidence furnished, and have collaborated cordially with the officials of the Treasury Department and those of the Department of Agriculture in securing compliance with the provisions of the act. It is true there has been some misunderstanding in regard to what the act means, and this misunderstanding has been shared, to some extent, by foreign governments; but this has not interfered in any way with the proper execution of the law. No attempt has been made to execute the law in any except the broadest spirit, and every courtesy possible within the proper construction of the law has been extended to those importers who innocently were violators of its provisions. It is gratifying, also, to know that the exporters in foreign countries, as a rule, have been eager to learn of the exact character of the requirements of the law, and in many cases have made an earnest effort to comply with them. Nevertheless, as in all cases, there are some instances where it is evident that compliance with the law will only be secured by its rigid execution and not by voluntary action. One unfortunate circumstance connected with the enforcement of the law is that up to the present time it has not been possible to inspect more than a very small percentage of imported products. It thus may happen that an article may be excluded at one time or at one port and the same article admitted at another time or at another port. This, of course, has the appearance of discrimination when in reality it is only a necessity that arises from impossibility of complete inspection.

TRADE NOTES AND RECIPES.

Inexpensive Preparation of Pitch.—To 300 parts of coal tar (anthracene oil) of the specific weight of 1.120 to 1.125 are added 102 to 108 parts of sulphuric acid, of 66 deg. Bé., and the whole heated gradually to about 300 deg. C. The water is evaporated by strong boiling. At the same time sulphurous acid is disengaged; this continues to the end of the reaction, which is noticed by effervescence of the residue, or oftenest, by a sample, a drop or two being thrown into cold water to test the consistency. The time required for the operation is from one and a half to two hours. The following is another method: 300 parts of coal tar are heated to 180 deg. or 200 deg. C. The water contained in the tar and the volatile oils escape during the heating. Afterward, about 60 parts of sulphuric acid of 66 deg. Bé. are added, and the heating continued until the desired consistency is secured.—Rev. des Produits Chimiques.

Fireproofing of Wood.—This is accomplished by saturating the wood with an aqueous or alcoholic solution of incombustible salts, and then drying the wood. The wood is first placed in a suitable receiver, and a vacuum produced. The solution, consisting of appropriate salts, water, and alcohol, is introduced into the receiver, and the wood is saturated with or without pressure. The solution is then drawn off, and the wood dried. The alcohol dissolves the resinous substances in the wood, and increases the penetrating power of the solution. When the excess of the solution is drawn off, the resins are eliminated, and the alcohol is evaporated in the desiccation. This is the Peddlé process. The alcohols should be such as evaporate readily, and capable of dissolving the resins, monatomic alcohols, as wood spirits, methylic alcohol, ethylic alcohol, the ordinary commercial alcohols. The proportion of alcohol must vary with the character of the wood, more being requisite when much resinous matter is present.

Acethylith.—A new use for sugar has been found in the lighting industry. As is known, in lighting with acetylene the generation of gas keeps on even after the water has been turned off, so that all the calcium carbide contained in the receptacle is decomposed. This gas, if it cannot be used at once, has to be kept in gasometers. In the preparation of acetylene on a small scale, where gasometers cannot be employed, all carbide remaining after the supply of the water is shut off is wasted. This evil a patented process is designed to remedy by surrounding the carbide with an envelope of sugar. The mass is sold under the name of acethylith, and is said to possess the advantage that with the shutting off of the water, all further decomposition of carbide ceases at once. By turning on water again the generation recommences immediately, no carbide being lost at all.—Neueste Erfahrungen.

Determination of Sulphur in Calcium Carbide.—Herr J. Lindholm recommends in the Zetischrift für angewandte Chemie a process which he makes use of for this purpose, by melting pulverized calcium carbide with 5 parts of potassic soda carbonate, chemically pure, and 2 parts of chemically pure anhydrous ammonium chloride. The fusion is readily effected, and the calcium carbide is decomposed, with separation of carbon. The sulphur existing in the carbide in the state of sulphide is not oxidized, and if a small part is oxidized by the oxygen of the air, the carbon, which is separated in a finely divided state, reduces it anew to the state of sulphide. The product of fusion, treated with acids, disengages the contained sulphur in the form of hydrogen sulphide. This is converted by oxidation, by means of brominated water, or oxygenated water, into sulphuric acid, which is estimated in the state of barium sulphate (or preferably by the Schultze method, as being more rapid), by the precipitation of the hydrogen sulphide as cadmium sulphide, and weighing under the form of cupric oxide.

Films and Filaments of Colorless Cellulose.—A solution of viscose is passed through narrow orifices into moderately concentrated sulphuric acid. A pellicle or filament is formed, to which sulphur or combinations of sulphur give a dull white appearance. After a rapid passage through the acid, the product is rolled on spools, with acid adhering. When a sufficient number of spools have been prepared they are plunged in a bath capable of freeing the product from the sulphur or combinations of sulphur. The researches of the German concern, the Vereinigte Kunstseidefabriken, have shown that solutions of sulphureted hydrates, sulphides, sulphites, and bisulphites of the alkalies and alkaline earths cause a desulphuration, and furnish a brilliant colorless product. When the solutions are concentrated, they may be employed cold, but it is better to heat them to 60 deg. or 80 deg. C. The reaction then occurs rapidly, even in weak solutions. A solution of about eight per cent of hydrated sodium sulphide or ammonium sulphide or sulphite, or bisulphite of soda, gives the best results. When the filaments or films have been rendered colorless and brilliant, they are washed with hot water and dried.

ENGINEERING NOTES.

It should be noted that girder work, whether of wrought or cast iron, when imbedded in lime or cement concrete, or mortar, generally proves to be very well preserved, provided that close contact has obtained. Cast-iron girders, when carrying jack arches resting upon the bottom flanges, are found after long use to be in remarkably good order, when finally taken out, having, indeed, the surface appearance of new girders. Much the same remarks apply to girders of wrought iron carrying jack arches, where protected by the brickwork; provided that the girders are sufficiently stiff to minimize deflection, and allow the masonry or brickwork to adhere to the surfaces.

Sulzer made the greatest step in the balancing of compound centrifugal pumps by placing the impellers back to back in pairs, so that one impeller thrust in one direction and the next impeller thrust in the opposite direction. The method which he used, however, of conveying the liquid being pumped from one impeller to the next required short, tortuous passages, he utilizing the fixed guides in the whirlpool space of the pump to form these cross-over passages; also, it is believed, that to Sulzer we are indebted for the idea of introducing the guide blade or turbine element. John Richards followed Sulzer in placing two impellers back to back and differed from Sulzer in passing the discharge from one impeller out and around the discharge chamber of the final impeller, but only showed this construction in a two-stage pump.

The merit of having entered upon the new path which the construction of gas-engines has followed for five or six years undoubtedly belongs to the Germans. The old makers of gas-engines in Germany took the initiative of departing from old methods. In a short time their processes were themselves improved and perfected by the makers of steam-engines, long accustomed to circumvent or overcome practical difficulties in the construction of large engines. Large gas-engines tending toward a single type all have manifest tendencies to resemble the modern steam-engine from the point of view of their form and valve gear. Having regard to the fact that valves are the common means of distribution, that they are operated by a side shaft, and that large engines now work double acting, it was natural and logical that the explosion machine should borrow from the steam-engine the design and methods with which it has been equipped in its long and victorious career. The introduction and growth of suction gas-producers and the utilization of blast-furnace gas, coke-oven gas, etc., which have marked the development of large gas-engines, have led to the creation of different designs for their construction. Different principles have thus been modified in their applications, such as the regulation, the compression, the cooling, the ignition. Without dwelling upon the different stages of their transformation, it will be shown in what way modern methods differ from old methods, and the probable direction of future change, having regard to the knowledge and practical experience already acquired.

According to Engineering News, fourteen submarine tunnels are now under construction or under contract to connect Manhattan Island with New Jersey on the west or Long Island on the east. The latest tunnels to be placed under contract are the two tunnels of the New York and Long Island Railroad, to run from Third Avenue and 42d Street, New York city, under the East River to a connection with surface electric roads on Long Island. At the Manhattan terminus a large subterranean station will be excavated, about 80 feet below the level of the Manhattan subway lines. The great air capacity required in present-day submarine tunnel work is well illustrated by a contract just closed for air compressors by the Degnon Contracting Company, which has the contract for building these two tunnels. The company has just ordered from the Ingersoll-Sergeant Drill Company fourteen air compressors of two different types. Eight are of duplex compound class "HC" pattern with steam cylinders 16 and 28 inches in diameter, air cylinders 25¼ and 16¼ inches in diameter, and a stroke of 16 inches. Each unit has a free air capacity of 1,205 cubic feet per minute. The other six are of straight-line class "A" type, with a 24-inch steam cylinder, 26¼-inch air cylinder and a stroke of 30 inches. The capacity of each is 1,444 cubic feet per minute. The aggregate free air capacity of the fourteen compressors is 18,304 cubic feet per minute. The shield method will be used in driving these tunnels. The straight line compressors will furnish air to the headings for keeping out the water, and will also supply intake air to the other machines. The compound units, drawing their air at discharge pressure of the low-pressure machines, will furnish air at high pressure to the rock drills and other machinery in the tunnel bores. As at present planned, the work of driving these tunnels contemplates three shafts. One will be at the Long Island terminus; another at 42d Street and the river front in New York. The third will be on Man-o'-War's Reef in East River, and some interesting work will be done here in providing room for a power plant. Ultimately it is expected that quite a large island will be made here with the rock removed from the tunnel. From this central shaft, the tunnels will be driven in both directions. The fourteen compressors will be distributed among the three plants. This last order makes a total of fifty-four Ingersoll-Sergeant air compressors in use or contracted for on sub-aqueous tunnels entering New York city. The aggregate free air capacity of these machines is 138,426 cubic feet per minute, and the pressures delivered range from 30 to 150 pounds.

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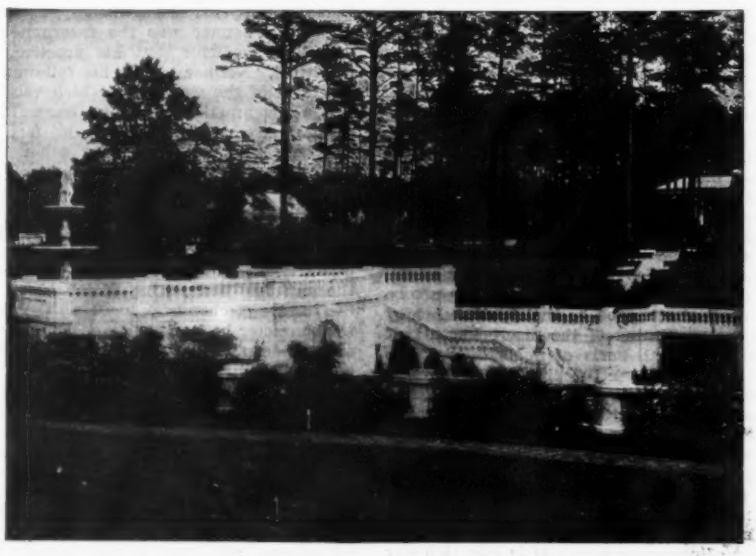

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